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The Keystone Bridge Company's

ILLUSTRATED

ALBUM

EMBRACING

Iron Bridges, Roofs, Columns, Chord Links, and Shapes,

WITH

DESCRIPTION OF LONG-SPAN BRIDGES,

Quality of Materials, and Principles of Construction.

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REMOVAL.

THE PHILADELPHIA OFFICE of the Keystone Bridge Company has been removed from No. 426 Walnut Street to the CAMBRIA IRON COMPANY'S BUILDING, **No. 218 SOUTH FOURTH STREET**, opposite the General Offices of the Pennsylvania Rail Road Company and the Philadelphia & Reading Rail Road Company.

DESCRIPTIVE CATALOGUE

OF

WROUGHT-IRON BRIDGES

FIRE-PROOF COLUMNS AND FLOOR GIRDERS, WROUGHT-IRON ROOF TRUSSES, WROUGHT-IRON
TURN-TABLES, PIVOT BRIDGES, PARK BRIDGES, SUSPENSION BRIDGES,
COLUMNS, LINKS, AND BRIDGE BOLTS,

MANUFACTURED BY

THE KEYSTONE BRIDGE COMPANY.

PRINCIPAL OFFICE AND WORKS, PITTSBURGH, PA.
PHILADELPHIA OFFICE, 426 WALNUT STREET.
WESTERN OFFICE, 211 WASHINGTON AVENUE, ST. LOUIS, MO.

ALLEN, LANE & SCOTT,
RAILROAD AND MERCANTILE PRINTERS,
233 SOUTH FIFTH STREET, PHILADELPHIA.

OFFICERS, 1874.

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PREFATORY.

IN offering our Illustrated Catalogue to the leading railway companies who have heretofore so generously patronized us, and to the public so vitally interested in the safety of bridge construction, we respectfully submit a few hints that may form a safe guide in determining the class of structures adapted to their respective wants.

Classified examples of different styles of bridges, adapted to various spans and localities, have been included, accompanied by descriptions of their ruling characteristics.

Wood-cuts, from photographs of some of the great structures erected by this Company, with brief descriptions of the same, have been inserted, with the belief that truthful representations of important executed works, while in themselves interesting to the engineer, afford surer indications of the ability and resources of their constructors than the most elaborate series of projected designs and pages of extravagant professions.

A continuance of the very liberal patronage heretofore bestowed is respectfully solicited, and we assure our patrons that we shall endeavor, by means of our improved machinery, increased facilities, and ripened experience, to render our work, in quality of material, beauty of design, accuracy of proportions, perfection of workmanship, and adaptation to locality, superior to any heretofore constructed.

KEYSTONE BRIDGE COMPANY,

PITTSBURGH, PA.

OLD SHOPS.

THE KEYSTONE BRIDGE COMPANY.

This Company was organized in 1865, with a capital of $300,000, absorbing the firm of Piper & Shiffler, who had erected bridge works in Pittsburgh in 1863, and executed many important works.

By a very liberal charter, granted by the Legislature of Pennsylvania in 1872, the Company was authorized to increase its capital stock to $1,500,000, and the privilege was conferred to construct general machine-work, and the substructure and superstructure of buildings, bridges, and other constructions of wood, iron, steel, stone, and other material, in any part of the United States.

After numerous additions to the original works, the new and complete works, of enlarged capacity, were erected on a lot embracing six acres of ground purchased for this purpose.

The accompanying illustrations show the original bridge works of Piper & Shiffler, subsequently enlarged and improved by the Keystone Bridge Company, and also the new works erected by the latter Company, including machine-shops, smith-shops, riveting-sheds, bolt-cutting and testing houses, pattern-shops, a large iron building for a foundry, offices, stables, and all the accessories of a first-class establishment.

In the completeness, extent, and adaptation of all the tools and appointments required for heavy bridge construction, the works of this Company are without a rival in this country, while, at the same time, they possess every facility requisite to the construction of iron roofs, fire-proof buildings, turn-tables, roadway bridges, wooden bridges, and general foundry and machine work.

The annual capacity of these works is now about $3,000,000. These facilities are being constantly increased, and further extensions of the works are now in progress.

NEW BRIDGE WORKS.

It results, as an invariable sequence of the law of demand and supply, that one great industry calls into existence other allied manufactures especially adapted to facilitate and enlarge its productions. The demand for new forms of iron in our improved bridge construction, embracing channels, beams, hollow columns, and "upset" or weldless tension chords, was promptly met by Messrs. Carnegie, Kloman & Co., who erected large works adjacent to the shops of the Keystone Bridge Company.

The intimate relations existing between these companies, and the immediate proximity of their respective establishments, afford the opportunity of observing and directing the special manufacture of the iron employed by us in bridge and other work, in all the varied manipulations from the ore to the finished bar.

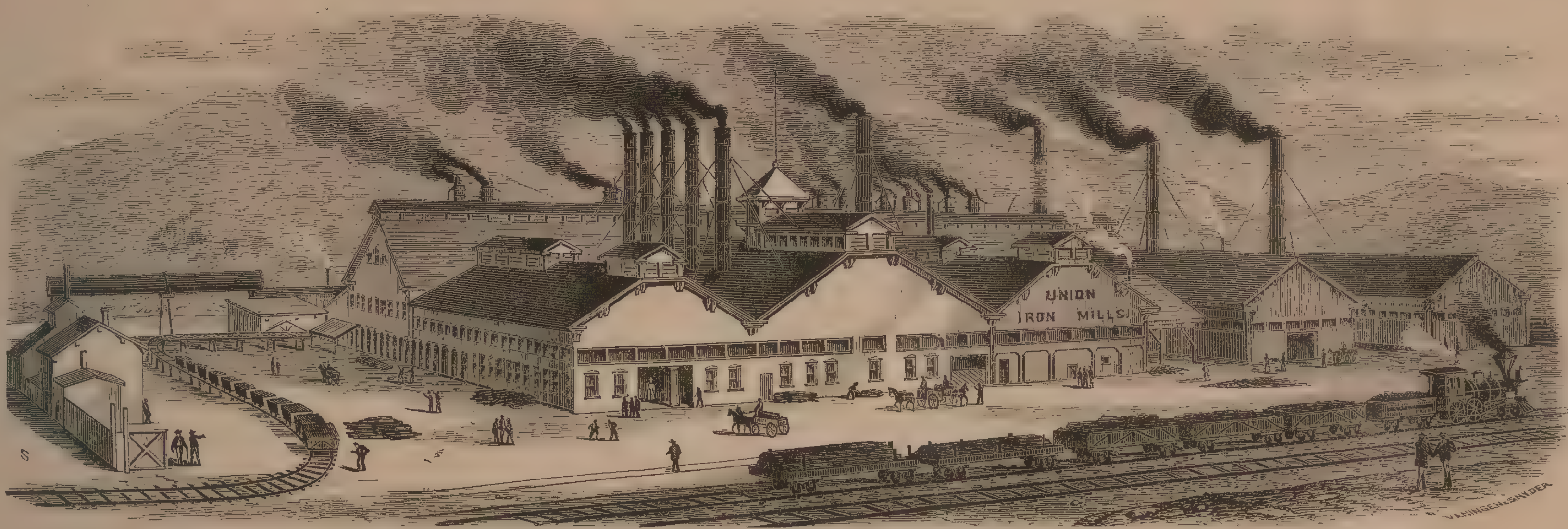
The quality of the ore and fuel employed, as well as the improved methods of heating and working the iron, are a guarantee that the quality furnished by these and other large mills in Pittsburgh cannot be surpassed for bridge construction.

Our ability to obtain at our works all shapes of iron, and any graduation in thickness and width of bars, rolled to unusual lengths, insures a prompt execution of all classes of bridge and other work intrusted to us.

By watching each step in the process of manufacture, and by carrying out the careful system of tests instituted by us, not only at the mills,—where the bars are piled, rolled, and rerolled, and in the smith-shop, where every precaution is observed by skilled foremen to detect imperfections,—but also at our works, by constant tests of specimens cut from bars designed for bridges, we are enabled to determine whether the material, mixture, and working of the iron are such as to render the quality satisfactory.

When the quality is discovered to be below our requirements, the causes can be, at once, determined. The mixture and kind of ores are then varied, and such care observed in the manufacture as will produce results in conformity with our specifications.

A short description, with illustrations of the furnace and Union Iron Mills, has been furnished for insertion.



UNION IRON MILLS.

THE UNION IRON MILLS—CARNEGIE, KLOMAN & CO.

The Union Iron Mills are located between the Allegheny Valley Railroad and the Allegheny river, in the Fifteenth ward, Pittsburgh. They occupy about eight acres of ground, and consist of two distinct and complete rolling-mills, only one of which is shown on the accompanying sketch, it being the intention of the firm to consolidate the works at an early day. The works contain thirty-seven puddling furnaces, fourteen heating furnaces, seven trains of three-high rolls, and one "Universal Plate Mill." The beam train and also the eighteen-inch bar train are perhaps the most complete mills in the country; they are covered by a fire-proof building and are operated with five Seimen's heating furnaces. The beam train has a capacity of five hundred tons of beams or channels per week. The sections made on this mill include ten sizes of channels and twelve sizes of beams, varying from three pounds per lineal foot to sixty-seven pounds per foot. The eighteen-inch mill is specially adapted for large flats, rounds, and squares, of unusual sizes or lengths, and for angles, **T** bars, and other shapes. Of these sections, there are rolls for twenty-two different sizes of **T** bars, varying in weight from two pounds per foot to thirty-five pounds, and including a number of sections made specially for the United States Navy Department. The list of angles and **L**'s is also complete. The other roll trains—eight, twelve, fifteen inch, &c.—are used for ordinary bar sizes, from three-sixteenths inches round, square, or flat, upwards.

The "Universal Mill" was the first successful mill of the kind in this country. It is an improvement (patented by Mr. Kloman) over similar mills in use in Europe, and is designed especially for rolling heavy flat bars or plates up to thirty-six inches in width, with sound and true edges, avoiding the necessity of SHEARING. Bars or plates to thirty-six inches in width, and of any desired thickness, are rolled on this train. The quality of all the iron made is specially adapted for bridges, or other structures where quality is essential. The pig metal used is made by the firm at their "Lucy" furnace, which is located a short distance from the mills on the river and railroad. The height of the stack is 75 feet, and the diameter of the base 20 feet. At the time it was built (1872) it was the largest

LUCY FURNACE.

furnace in the United States. Since it has been in successful operation two or three other furnaces have been erected, in different parts of the country, of the same diameter of bosh. The blowing-engines, three in number, (one being in reserve,) are direct-acting vertical engines. The diameter of the air-cylinders is 84 inches, the stroke 48 inches. The steam-cylinders have a diameter of 35 inches, with 48 inches stroke. The steam-boilers, eight in number, are plain, cylindrical boilers, 42 inches in diameter and 60 feet long. The hot-blast stoves, four in number, are a modification of the "Player" patent. The boilers and hot-blast stoves are supplied with gas from the stack—no coal or other fuel being used. The ore smelted is brought from Lake Superior from the celebrated "Kloman" mine, the property of the firm. The mine yields two kinds of ore—"specular" and "magnetic," both of which are found "in place" in the same general vein, although not intermixed. The specular ore is red-short, and makes a fine quality of Bessemer metal, and a very high grade of forge iron (red-short). The magnetic ore produces excellent foundry iron and an equally good forge iron (neutral). By a mixture of these ores, either red-short, cold-short, or neutral iron can be produced. The average yield in metallic iron from these ores is sixty-seven per cent. from the "specular" and sixty-eight and one-half per cent. from the "magnetic." The average production in metal by the "Lucy" furnace has been the largest known weekly production.

The fuel used is coke made from the slack of Pittsburgh coal, twenty miles from the works, on the line of the Pennsylvania Railroad, at Cokevale station. The slack is washed by machinery before coking—the sulphur and shale being entirely eliminated. The coke produced by this process is of a very superior quality. The yield of the furnace in metal, and the reputation it has acquired, is in no small measure due to the excellent quality of the coke—to the manufacture of which great care is given.

All the buildings about the furnace are strictly fire-proof, and are arranged for two stacks. A portion of the machinery for the second stack is now on the ground.

The general office of the firm is on Thirty-third street, Pittsburgh; the eastern office at 57 Broadway, New York.

The following shows the results of comparative tests made of various irons from stock at St. Louis:—

DESCRIPTION AND MAKERS OF IRON.	Number of pieces tested.		Average tensile strength per square inch.	
	Parallel cylinders.	Grooved cylinders.	Parallel cylinders. Pounds.	Grooved cylinders. Pounds.
“Sligo,”	3	3	41,963	48,330
Round “B,” from Southers & Co., . . .	3	3	49,440	54,310
“B,” from Graff, Bennett & Co., ...	3	3	47,390	53,400
“Tennessee,”	6	6	46,360	54,273
“Tennessee,”	3	3	47,030	54,300
“Kentucky,”	9	9	47,937	54,463
Chouteau, Harrison & Valle, ...	3	3	51,510	58,510
“Sable,”	3	3	49,060	56,493
Carnegie, Kloman & Co..	. .	1	. . . .	63,300
Carnegie, Klon				
Carnegie, Klon				

Specimens of iron furnished by Messrs. Carnegie, Kloman & Co. for the great double-roadway iron bridge, 348 feet span, being erected by the Keystone Bridge Company, over the Schuylkill river, at Fairmount, Philadelphia, are subjected to tests at our works, as the different forms of iron are manufactured.

The resistance to rupture is shown in the following table, recording the first series of tests:—

SHAPE OF SPECIMEN.	Diameter of specimen. Inches.	Breaking strain per square inch of specimen. Pounds.	REMARKS.
Grooved cylinder, . .	.75	65,500	Cut from a round bar 1¼ inches diameter.
“ “ . .	.75	68,174	
“ “ . .	.75	64,163	“ “ 1⅜ “ “
“ “ . .	.75	65,500	
“ “ . .	.75	62,826	“ “ 1½ “ “
“ “ . .	.75	65,500	
“ “ . .	.75	64,163	“ “ 1⅝ “ “
“ “ . .	.75	60,153	
“ “ . .	.75	65,500	“ “ 1¾ “ “
“ “ . .	.75	69,500	“ “ 1⅞ “ “
“			

LONG-SPAN BRIDGES OF AMERICA.

The application of iron and steel to the construction of bridges of considerable span is of recent date in this country.

As late as 1862, it is believed that the Green river bridge and the Monongahela, with spans of 200 feet, by Fink, and the Schuylkill bridge, by J. H. Linville, with spans of 192 feet, were the longest iron spans in the United States.

The tubular bridges at Montreal and over the Menai Straits, by Stevenson, and the parabolic truss at Saltash, by Brunel, were the greatest spans erected by English engineers.

The Steubenville bridge, containing a span 320 feet in length, was the *pioneer* of long spans in the United States. Its design and construction were intrusted, in 1862, to J. H. Linville, C. E. In the execution of the work special provision in tools, machinery, testing apparatus, and appliances for erection, was rendered necessary in consequence of its unusual dimensions and proportions.

The Monongahela bridge at Pittsburgh, with a span of 260 feet for double track, was constructed simultaneously from the same [illegible]

[illegible] Baltimore and Ohio Railroad Company's bridges over the Ohio at Bellaire and Parkersburg, with spans of 350 feet, and the great span of 420 feet in the Newport and Cincinnati bridge at Cincinnati, all of which were constructed by the Keystone Bridge Company, from designs prepared under the immediate supervision of their President.

The Parkersburg bridge has two spans of 348 feet, four of 200 feet, with numerous shorter spans. The Bellaire bridge has one span 348 feet, one of 250 feet, four spans 200 feet, and a number of 107 feet spans, the approach consisting of forty-three stone arches, 28 feet 4 inches each, on a five-degree curve. Cost about $1,000,000. J. L. Randolph, Chief Engineer.

The Louisville bridge, constructed by Albert Fink, contains the next longest span in the United States, being 400 feet in length. Spans of 300 feet have been erected at St. Charles by Shaler Smith, and over the Missouri river at Atchison by the Detroit Bridge Company.

The cut illustrates the system of construction adopted at Steu- [illegible] ed from [illegible] cinnati bridge. This is the longest truss in use in this country. The same general design, submitted by J. H. Linville, Chief Engineer, has been selected and approved for the great bridge over the Hudson at Poughkeepsie, N. Y., with five spans of 525 feet each.

These will be the longest spans of truss-bridge ever attempted in this or any other country. The success of previous works, on similar plans, is the best evidence of their practicability for extended spans.

The distance from high water to the lower chord is limited by the charter to 130 feet.

The grade will be elevated 190 feet above high water.

The eastern approach consists of four spans of 260 feet, and five spans of 135 feet, at varying elevations.

The depth of water varies from fifty to sixty feet. The immense height of structure, length of spans, volume of water, and depth to rock, render this project probably the grandest and most difficult that engineering skill has ever been required to undertake and accomplish.

Pivot bridges were generally constructed, previous to 1860, of two disconnected spans, sustained by guys depending from a central tower, or with guys to aid in stiffening wooden trusses.

In the Schuylkill bridge these accessories were omitted, the trusses being designed to be self-supporting when revolved on the pivot centre.

This method of construction now prevails almost exclusively. The accompanying illustration, taken from the Keokuk bridge, shows the pivot span, 387 feet in length.

CONNECTICUT RIVER BRIDGE, MIDDLETOWN, CONN.

GENERAL PRINCIPLES OF CONSTRUCTION.

The early examples of iron bridges constructed in the United States bear a striking resemblance to their wooden prototypes. It is apparent that, in designing these structures, due care has not been observed in estimating the effects resulting from moving loads, or in proportioning and combining the parts to offer the highest resistance.

Many portions of these bridges present an excess of strength, while other parts are deficient in size and so imperfectly united as to render them valueless.

It is true that later builders have avoided many of these errors, but instances of erroneous construction are still of frequent occurrence.

It too often happens that parts resisting tensile stresses are not combined in such manner as to render the entire sectional area efficient in sustaining loads. By some of the methods employed in connecting bars and plates a loss of twenty to thirty per cent. is caused by screw-threads and rivet-holes.

By varying the form of cross-section and the manner of combining pillars or struts with the other members of a truss their efficiency may be greatly increased and much useless material saved. The extraneous weight resulting from such defects in proportion, form, and connections must be carried by the efficient portions of the material, reducing considerably the available strength of the bridge.

But accuracy in proportion and refinements in the methods of combining the parts do not embrace all the prerequisites to insure immunity from accidents. The quality of materials employed and the limit of strain assumed are, perhaps, more important elements of security.

Perfection of workmanship, by which each part is made to fit accurately and bear uniformly its due proportion of stress, precludes uncertainty of action in the numerous parts of a complicated structure. While numerous failures of bridges and roofs have resulted from inaccuracy in proportions and a deficiency of materials, instances are not wanting in which similar catastrophes are directly traceable to the use of an inferior quality of iron and unskilled workmanship.

The unexampled success of the Keystone Bridge Company in the manufacture and erection of railway bridges, roofs, and other engineering works, has followed as the legitimate result of well-digested plans and sound principles of construction.

Discarding alike the foreign precedents of splendid but expensive engineering, and the early American examples,—crude in design, defective in quality of material, proportions, and details of construction,—the officers of this Company, by the application of scientific principles, careful observation, and mature judgment, influenced and corrected by practical experience, have originated and brought to perfection a class of railway structures which, in material, design, proportion, and details of construction, have not been excelled in this or any other country.

Their distinguishing features are lightness, strength, and economy, attained by employing wrought iron in tubular forms for compressive strains, and weldless links in tension members.

The forms of iron rolled to shape for use in tubular struts, chords, and arches, and the upset links and bars, are now generally specified for all first-class structures.

The superiority and economic value of tubular forms for struts or compressive members, and weldless ties for tension members, (by the employment of which a minimum weight with a maximum strength is attained,) are self-evident.

No surer indication of the popularity and efficiency of these forms is necessary than is afforded by the efforts of other builders to meet the demand by introducing the prominent features of these inventions.

The patents owned or controlled by this Company cover numerous details of great value in construction.

Among these may be classed hollow wrought-iron columns of various approved forms; tension chords and suspension bars, manufactured by our improved processes; the disposition of lower chords and suspension ties between ribs on the bases of the posts, and the provision for inspecting and repainting every part of the iron work.

While tubular chords may be well adapted, theoretically, to resist the direct compressive strains, the necessity for intermediate joints of cast iron at every post to facilitate the connection with the struts and ties, and the danger of deterioration by oxidation, render their use of doubtful expediency.

The early decay of all such structures will soon induce careful and conscientious engineers to exclude them.

In the bridges erected by the Keystone Bridge Company, provision is made for painting the interior of struts by spreading apart the bars composing them. The increased first cost is more than compensated by the greater durability of such structures. It is obvious to any reflecting mind, that very thin tubular columns placed over damp situations must be seriously weakened by corrosion in a few years, while columns that can be kept constantly repainted may be preserved indefinitely.

In designing and constructing bridges, the following points deserve consideration:—

I. The exercise of care and discrimination in the selection of materials.

II. Accuracy in proportion.

III. The employment of materials—subjected to strains of tension or compression—in the form best adapted to resist these strains; by this means securing the *maximum* of strength with the *minimum* quantity and weight of material.

IV. Perfection of details and connections, by which is secured the greatest efficiency of the materials employed.

V. Special adaptation of every structure to the locality, and the service it is required to perform.

VI. Specifications of the loads to be carried, factor of safety, quality of materials, details and character of workmanship that have been demonstrated by investigation and experience to be essential to insure the requisite strength, safety, and durability of bridges designed for roadway and railway traffic.

A few pages will, therefore, be devoted to the following subjects:—

1. Quality and strength of materials.

2. Proportions of structures.

3. Tension and compression members.

4. Form and arrangement of details.

5. Adaptation to locality and service.

6. Specifications.

MATERIALS USED IN CONSTRUCTION.—When any material is strained either by a tensile or a compressive force, the elastic reaction of the fibres (equal to the force applied) is proportional, within certain limits, to their extension or compression.

Beyond this limit the law as above stated ceases to apply; and the change of length no longer regular, increases more rapidly with each additional unit strain applied, than the reaction due to the elasticity of the fibres. Permanent *set* and, ultimately, *rupture*, must result from the continued application of increased weights.

The sensible limit of uniform elastic reaction is termed the *limit of elasticity*.

The weight in pounds requisite to elongate or shorten a bar the transverse sectional area of which equals one square inch, by an amount *equal to its length*,—on the imaginary hypothesis that the law of elasticity holds good for so great a range,—is termed the modulus, or co-efficient of elasticity. This co-efficient, designated by the symbol E, can be correctly deduced only by carefully-conducted series of experiments, in which the applied unit of strain lies within the limit of elastic reaction.

It is self-evident, on the hypothesis that the extension or compression will be proportional to the weight applied, that the elongation λ, of a bar one inch square due to the applied weight per square inch f, will be to that weight, as the length l of the bar is to E, the modulus, or weight required to extend it a length equal to l;

$$\text{or } \lambda : f :: l : E$$

$$\text{whence } E = \frac{fl}{\lambda} \quad \text{and } \lambda = \frac{fl}{E}$$

These expressions are of convenient application in determining the *modulus of elasticity* from experiments on bars of any length, and the extension or compression of bars due to any applied weight.

To vary the expressions for any sectional area S, the total strain F applied must be divided by the sectional area S, and the general formula for any cross-section will consequently be as follows:—

$$E = \frac{Fl}{S\lambda} \qquad \lambda = \frac{Fl}{SE}$$

It has been proved, by a series of carefully-conducted experiments, that wrought-iron bars extend about .00008 part of their length for each ton of two thousand pounds applied weight per square inch of sectional area, or $\frac{1}{12500}$th part of their length per ton per square inch. This uniform rate of extension holds good until the applied weight has been increased to ten or twelve tons per square inch, after which the bars rapidly stretch, with greater or less regularity, depending upon the quality of the iron.

The limit of elastic reaction is reached, according to some authorities, at about ten tons per square inch, and the co-efficient of elasticity usually adopted, both for tension and compression, is 24,000,000 pounds per square inch.

If a bar of iron one inch square and ten feet long stretch .00008th part of its length per ton per square inch, the co-efficient of elasticity would be $E = \frac{2000 \times 10 \times 12}{.00008 \times 10 \times 12} = 25{,}000{,}000$ pounds.

The following experiments on temporary cable links for St. Louis bridge were made at our works to determine the modulus of elasticity :—

Experiments made on Six Upset Link Bars to determine their Modulus of Elasticity.

Nominal size, 6½ inches × 1 inch. Area, 6.5 square inches.

Actual average size, 6.55 inches × 1.04 inch. Area, $6\frac{8}{10}$ square inches.

Length of bar centre to centre of pin-holes, 27 feet 6 inches.

Length of bar on which "λ" was observed, 26 feet = 312 inches.

No. of bar.	Ram pressure per sq. in. Pounds.	Ram area. Square inches.	Strain on bar. Pounds.	Area of bar. Square inches.	Strain per sq. inch on bar f. Pounds.	Length of bar l. Inches.	Extension in $l = \lambda$ Inches.	Modulus. $\frac{l\,f}{\lambda} = E$.
1	250	260	65,000	$6\frac{8}{10}$	9,558	312	0.120	24,850,800
2	250	260	65,000	$6\frac{8}{10}$	9,558	312	0.120	24,850,800
3	250	260	65,000	$6\frac{8}{10}$	9,558	312	0.120	24,850,800
4	260	260	67,600	$6\frac{8}{10}$	9,941	312	0.120	25,846,600
5	400	260	104,000	$6\frac{8}{10}$	15,300	312	0.185	25,803,300
6	260	260	67,600	$6\frac{8}{10}$	9,941	312	0.120	24,846,600
6*a*	400	260	104,000	$6\frac{8}{10}$	15,300	312	0.185	25,803,300
								176,652,200
Average modulus on seven experiments,								25,236,030

This average modulus indicates an extension of $\frac{1}{12618}$th part of the length for each ton of two thousand pounds, applied strain, per square inch of sectional area.

By Hodgkinson's experiments, the co-efficient of compressive elasticity of wrought iron is 23,243,179 pounds per square inch, and of tensile elasticity, in annealed bars, 27,691,200 pounds per square inch. An elongation of .0008 per ton of two thousand two hundred and forty pounds per square inch, would indicate a co-efficient of elasticity equal to 28,000,000 pounds.

In testing materials previous to their employment in permanent structures, the proof strain should never exceed the limit of elasticity.

The practice of testing bars to, even, twenty thousand pounds per square inch is objectionable, inasmuch as the strains are greater than the material should ever be subjected to in a structure.

A better method is to test *specimen bars*, for modulus of elasticity and ultimate strength, and test the bars to be used in structures to one and a half times the strain per square inch assumed as the maximum working strain. This working strain for wrought iron in bridges, and structures subject to sudden shocks and vibrations, should not exceed one-half the limit of elastic reaction, or about ten thousand pounds per square inch.

In all bridges designed by this Company, this limit of strain has been adopted.

In addition to the tests for tensile strength, especial care is exercised in selecting best grades of western irons, (which are superior to the eastern anthracite metals,) and in the heating, piling, and rerolling, or triple-rolling the same.

The tensile strength of a specimen is not a certain criterion of its adaptability to bridge work. A very hard, brittle iron will frequently snap, at a very high strain, without any considerable elongation; while soft, tough, well-worked fibrous iron will elongate rapidly and break at lower strains.

The former will often break short, with crystalline fracture, and is, therefore, manifestly unfit for bridge work; while the latter is always reliable for strains within its limit of elasticity.

The testing-machine is indispensable in determining the relative moduli, the limit of elasticity, and the behavior of specimens subjected to strains of tension or compression.

Whether a specimen will snap short, after a slight elongation and diminution of area, or stretch considerably, with a marked decrease of the section, and the extent to which these changes occur, is readily ascertained by experiments made in a suitable apparatus.

While such experiments are valuable in determining certain qualities of the material, they fail to disclose many inherent defects.

The experiments of Kirkaldy, and the numerous trials made almost daily at our works, prove, conclusively, that cylinders of uniform diameter will break at from seven to ten thousand pounds less strain per square inch of original area than specimens of the same iron when tested in cylinders in which a short groove has been turned. The effect of this groove is to limit the locality of the breaking point, prevent any considerable elongation, and to cause the specimen to snap with less reduction of area.

It is further shown that a high breaking strain may, in some instances, be due to the iron being of superior quality, dense, fine, and moderately soft; but such results are generally due to hardness and the absence of ductility, the breaking strain failing, in most instances, to indicate the reliability and fitness of the material for bridge work.

The breaking strain of fractured area affords indication of the comparative ductility of different irons.

Frequent working improves the iron and renders it less liable to snap. A hard, dense iron is shown to be best adapted to resist compression.

The practical test of general quality and adaptation should be made in the smith-shop. By bending cold, heating, hammering, punching, welding, breaking, and other well-known processes, more reliable information can be obtained, as to the purity, density, toughness, and other qualities of the material, and its fitness for the purpose to which it is to be applied.

The decrement of length of wrought iron, subjected to compression, averages .0001 of the length, for each ton per square inch, until ten to sixteen tons per square inch have been applied, after which the specimen begins to bulge or distort.

In thin tubes or cells this distortion occurs with a pressure of thirty-six thousand to fifty thousand pounds per square inch of sectional area; the latter in short, hollow cylinders.

CAST IRON is a brittle material and liable to numerous defects.

The average ultimate tensile strength is about sixteen thousand pounds per square inch, and the resistance of short blocks to compression is about ninety-five thousand pounds per square inch. The ultimate extension of cast iron averages $\frac{1}{600}$th of the length, while the compression, under the same strain as is required to determine its ultimate tenacity, is $\frac{1}{775}$th of the length.

The decrement of length under compression, per ton per square inch, averages about .00018 of the length, while the increment of

TABLE OF TESTS.

No. of Test.	Original dimensions.			Dimensions after test.			Elongation. Per cent.	Distance between collars. Inches.	Strain per square inch. Pounds.	Elongation due to this strain.	Modulus.	Limit of elasticity.	Breaking weight per square inch.	
	Diameter.	Area.	Length. Inches.	Breaking diameter.	Breaking area.	Length. Inches.							Of original area.	Of breaking area.
1	0.999	0.785	10.5	0.935	0.687	11.5	.095	6.5	12,700	0.0032	25,790,000	22,900	49,400	56,300
2	0.998	0.782	10.5	0.873	0.598	12.25	.166	6.7	12,700	0.003325	25,500,000	25,500	54,000	72,000
3	0.998	0.782	10.5	0.936	0.688	11.6	.1047	6.8	12,800	0.00341	25,520,000	24,300	49,800	56,600
4	1.000	0.785	11.125	0.871	0.596	12.75	.1274	6.7	12,730	0.00315	27,070,000	25,400	47,770	62,900
5	1.003	0.790	10.5	0.840	0.554	13.00	.238	6.55	12,600	0.002925	28,200,000	21,500	48,700	69,400
6	1.002	0.788	10.5	0.887	0.618	12.4	.181	6.45	12,600	0.003	27,400,000	24,100	46,900	59,800
7	1.003	0.790	10.6	0.900	0.636	12.9	.217	6.525	12,600	0.0032	25,700,000	20,250	47,100	58,500
8	0.998	0.782	7.9	0.699	0.384	9.8	.24	3.6	12,800	0.00215	21,430,000	21,600	47,770	97,600
9	. . .	0.7917	12.00	. . .	0.4657	. . .	.242	6.68	. . .	. . .	28,100,000	28,000	56,840	96,629
10	. . .	0.7980	11.00	. . .	0.4418	. . .	.27	6.63	. . .	. . .	26,000,000	25,000	50,125	90,538
11	. . .	0.7854	11.00	. . .	0.5153	. . .	.23	6.3	. . .	. . .	30,000,000	27,000	49,814	75,927
12	. . .	0.8028	7.00	. . .	0.5675	. . .	.18	3.6	. . .	. . .	32,000,000	24,000	51,712	72,625
13	. . .	0.806	7.00	. . .	0.4536	. . .	.30	3.5	. . .	. . .	30,000,000	29,000	50,087	89,011
14	. . .	0.4477	7.00	. . .	0.2376	. . .	.253	3.75	. . .	. . .	30,000,000	28,000	50,536	95,223
15	. . .	0.4477	7.00	. . .	0.2552	. . .	.25	4.00	. . .	. . .	32,000,000	26,000	51,373	90,126

These tests were made with uniform cylindrical test pieces, without a "groove" or "breaking-point" being turned in them.
Nos. 1 to 7, inclusive, were single-rolled, hard iron, from Messrs. Spang, Chalfant & Co.
No. 8, single-rolled, soft, fibrous iron, from Messrs. Lyon, Shorb & Co.
Nos. 9 to 15, double-rolled, soft, fibrous iron, from Messrs. Carnegie, Kloman & Co.—Tests made by C. A. Uber, U. S. N.

length under tensile strains averages .00024 of the length per ton per square inch.

Changes of temperature affect cast iron more than wrought iron, the relative rates of expansion for wrought and cast iron for a change of 1° F. being .0000069, and .0000062 of their length.

Cast-iron tubular columns and chords are liable to inequalities in the thickness of the metal.

The buoyancy of the liquid metal causes the cores to rise. It is, consequently, difficult to maintain them in their true central position.

The impurities of the metal frequently settle to the lower side of the casting, and the metal flowing from different inlets chills before meeting.

These, and the efforts of confined air to escape, cause the castings to be of unequal thickness, and to present numerous defects, such as honey-comb, cold-short, blow-holes, &c., while rapid and unequal cooling produces inherent strains and renders the casting liable to break under slight shocks.

Tubular castings for bridges should be cast on end, in dry-sand moulds. The metal should be carefully skimmed, and the casting should be allowed to cool slowly and uniformly.

By this process, carefully conducted, many of the defects incident to tubular castings may be avoided.

Upper chords of cast iron, made in this manner and designed so as to exclude water, can be safely used in bridge construction; but a decided preference is given by this Company to columns and compression chords entirely of wrought iron.

Cast iron is used by this Company only in short blocks or flat, solidly-bedded plates, which are subjected to compressive strains, and, in some instances, in bases and capitals of posts, washers, gibs, &c. Should any portion be subjected to tensile strain, the safe limit is assumed at one and a quarter tons per square inch.

Cast steel is readily injured by heating, upsetting, or punching, welds with difficulty, and snaps readily at any shoulder or indentation. Unless forged to the form in which it is to be employed, it cannot be advantageously used in tension members of bridges.

Large bars of steel break at low strains when attachments are made on the surface, as by nuts or collars. This is probably owing in a great measure to the unyielding nature of the material. The surface cracks before sufficient elongation occurs to permit the strain to be diffused throughout the entire mass, and the bars consequently fail in detail.

The imperfect working of large bars, and the inherent strains produced by drawing, may account for a considerable reduction in their comparative strength.

Investigations were made in 1857 by the President of this Company to determine the applicability of cast steel to bridge construction. It was not found advantageous except for compressive members of long spans where the saving of dead weight becomes a primary consideration. Its use, in the Illinois and St. Louis bridge, being constructed by this Company according to the designs of James B. Eads, Esq., has afforded opportunities for making experiments with large masses, which confirm the above conclusions.

When the requisite provision is made to resist flexure, steel of high quality may be safely subjected to compressive strains equal to one-half its elastic limit, which ranges from forty thousand to sixty thousand pounds per square inch of sectional area.

Tension members of steel should be made of small, well-worked bars, forged to the form required, without welding or upsetting.

In connecting-pins it may be employed to advantage.

It is believed that true economy indicates the exclusive employment of wrought iron and wrought steel, in the most approved and durable forms, in bridge construction.

The material should, in all cases, be manufactured with special reference to the duty required of it, so that, in quality and form, it may be best adapted to resist the stresses to which it may be subjected.

That its strength may not be impaired by the rapid and certain reduction of area by oxidation, it is imperatively necessary to make the requisite provision for repainting all portions of the structure.

PROPORTIONS OF STRUCTURES.—Bridges should be proportioned that each part will have the same relative strength as all the other parts, within the elastic or safe limit, under the maximum effects resulting from their dead load and the maximum moving loads, due allowance being made for the destructive effects of impact and vibration.

The panel system and floor-girders should be designed to sustain weights varying as the length of panel, to be determined by ascertaining the greatest possible weight that can be made to occupy a given girder, or a given length of track equal to one panel, by the heaviest locomotives in use on the line.

The chord system should be proportioned for the heaviest possible load that can be thrown on the bridge by assuming an excess for impact and vibration over the average weight per lineal foot of the heaviest trains. On all railways it is a frequent occurrence for several engines and tenders to be coupled together, drawing heavy trains.

The strains on the chord system, determined by combining the effects of the uniformly distributed and the assumed average variable or moving load covering the entire bridge, must be increased by the increments of strain due to the effects of the excess of engine-load, on the panel system, over this average distributed load.

If an engine be placed in the middle of a long train covering the entire bridge, or in advance of a train and closely following the rear of another train, equal in weight per lineal foot to the assumed maximum average load, it is evident that the maximum stress on the centre of the chords will occur when the engine is at the centre of the span, and the increment due to the excess of engine weight over the assumed variable load, uniformly distributed, will decrease, in a certain proportion, as the engine approaches the end of the span.

An increase of the strength of the panel system, without increasing the chord system, can be justified only on the supposition that such a distribution of the load, as has been described, may never occur.

Every engineer and railway man can recall instances when several engines have been coupled together, in removing snow, &c., or in drawing heavy trains.

New locomotives, of the heaviest class, are daily drawn in the midst of long trains laden with heavy freight.

These resultant strains, caused by possible concentration of loads, must be considered in all well-proportioned structures. Their omission by many bridge-builders undoubtedly economizes materials, by reducing the chord section, and thereby diminishes the cost, but cannot be justified by correct reasoning.

It is a well-established fact that the live load is more injurious to the parts of a bridge than the stationary or dead load. In short spans, where the dead weight is small in comparison with the live load, and where the engine and tender nearly, if not entirely, cover the entire span, the injurious effects produced by the live load are readily perceptible.

The deflections, and the destructive effects caused by a moving load, increase with the speed of trains; and trains generally pass short spans at maximum speed.

These and other obvious considerations render it essential, in proportioning bridges, to assume a uniformly distributed live load *in excess* of the probable weight of average trains. This must be combined with the excess of panel weight deduced from the portions of the weights of the heaviest engines concentrated on a wheel base equal to the panel length. Allowance may also be made for the increased average weight, per lineal foot, occupied by engine and tender on an adjacent panel.

This excess of engine weight over average variable load should be greatest for short spans, and may be diminished as the length and dead weight of span increase.

The engine designed for the Newport and Cincinnati bridge weighs over thirty-nine tons, on a wheel base of ten feet. This is not an isolated example.

For main lines of traffic, it is not considered prudent to assume less than forty tons in a span of twelve feet,—stringers spanning over twelve feet should be sufficiently strong to carry one and one-half tons per foot for each additional foot. The excess of average live load per lineal foot (exclusive of excess of engine weight) over the average weight per foot of heaviest trains is allowed, to compensate for the destructive effects of vibration due to impact and high speeds.

The following table of weights of engines, and average weight per lineal foot concentrated on drivers, has been compiled from the illustrated catalogue of the Baldwin Locomotive Works.

TABLE I.

	DESCRIPTION OF ENGINE.	No. drivers.	Dist. bet. centres extr'me drivers. Ft. In.	Weight on driving-wheels.	Average weight per foot of track on drivers.	Total wheel base. Ft. In.	Total weight of engine.	Average weight per lineal foot of track.
1	Passenger and freight, ...	4	6.6	30,000	4,615	20.1¾	50,000	2,480
2	“ “ “	4	7.0	35,000	5,000	20.7¾	55,000	2,660
3	“ “ “	4	7.8	39,000	5,087	21.3	60,000	2,820
4	“ “ “	4	8.0	45,000	5,625	22.6¼	70,000	3,111
5	Ten-wheeled freight, ...	6	12.1	51,000	4,220	23.0	67,000	2,910
6	Pushing-engine “ Mogul,” . . .	6	14.0	57,000	4,071	21.4	66,000	3,094
7	“ “ “ . . .	6	14.6	62,000	4,280	21.10	71,000	3,250
8	“ “ “ . . .	6	15.0	66,000	4,400	22.5	76,000	3,390
9	“ “ “ Consolidation,”	8	14.9	87,000	5,900	21.10	96,000	4,400
10	Switching-engine, separate tender,	4	6.0	34,000	5,666	6.0	34,000	5,666
11	“ “ “ “ .	4	7.0	38,000	5,428	7.0	38,000	5,428
12	“ “ “ “ .	4	7.6	56,000	7,466	7.6	56,000	7,466
13	“ “ “ “ .	4	4.8	30,000	6,430	11.3	35,000	3,111
14	“ “ “ “ .	6	9.9	52,000	5,333	9.9	52,000	5,333
15	Tank switching-engine, ...	4	7.0	49,000	7,000	7.0	49,000	7,000
16	“ “ “	4	7.0	56,000	8,000	7.0	56,000	8,000
17	“ “ “	4	4.8	35,000	7,500	11.3	40,000	3,555
18	“ “ “	4	7.0	50,000	7,142	14.7½	56,000	3,830
19	“ “ “	6	9.9	60,000	6,150	9.9	60,000	6,150
20	“ “ “	6	10.0	66,000	6,600	10.0	66,000	6,600
21	Pass'r and freight, narrow gauge, .	4	6.6	25,000	3,846	12.4½	30,000	2,424
22	Freight, narrow gauge, ...	6	8.7	31,000	3,610	14.3	35,000	2,340
23	“ “ “	6	9.4	36,000	3,880	15.4	40,000	2,670

In determining the greatest concentrated load that can fall on one panel apex of bridge (two trusses), we must consider the weight carried on a pair of drivers, and the distance between drivers, or the wheel base. A portion of the weight on drivers is transferred, by means of the rail-stringers, to the adjacent cross-girders and the apices of adjacent panels.

The greatest weight that can be thrown on the centre of the stringers, for different spans, may be determined in the same manner, and an equivalent distributed load may be assumed equal to twice the weight at the centre.

For instance, with engine No. 4 one pair of drivers would occupy the centre of an eight-feet span, and the equivalent distributed load would be twenty-two and a half tons, if we disregard the continuity of the stringers.

The following table for cross-girders for different panel lengths, and heaviest loads concentrated at apices of panels, has been compiled from Table I.:—

Table II.

ENGINE.	Number of drivers.	Wheel base.	Weight on one pair.	Weight on one floor-girder spaced as below.					Weight on one pair of stringers.			
				Two feet to five feet.	Seven feet.	Ten feet.	Twelve feet.	Fifteen feet.	Spans.	Weight at centre.	Weight distributed.	Weight per lineal foot.
		Feet.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Feet.	Tons.		Pounds.
Newport and Cincinnati,	6	10	13	13	18	26	28	30	5	13	26	10,400
No. 16, . . .	4	7	14	14	14	18	19	22	6	14	28	9,333
No. 18, . . .	4	7	12.5	12.5	12.5	16	18	19	7	13	26	7,428
No. 20, . . .	6	10	11	11	17	22	24	26	8	13	26	7,500
No. 16, . . .	. .	. .	. .	. .	. .	. .	. .	. .	10	14	28	5,600
N. and C.,. .	. .	. .	. .	. .	. .	. .	. .	. .	12	17	34	5,666
" " . .	. .	. .	. .	. .	. .	. .	. .	. .	15	20	40	5,333

Short spans of six to ten feet may be subjected to loads of twenty-six to thirty tons, and they should therefore be proportioned for a load of six thousand to nine thousand pounds per lineal foot. Spans fifteen feet in length should be proportioned to support fifty-five hundred pounds per lineal foot.

The centre load on a twenty-foot span from Newport and Cincinnati engine would be about twenty-five tons. The equivalent distributed load would be fifty tons. It will not therefore be safe to assume less than five thousand pounds per lineal foot, for spans twenty feet in length.

Spans twenty-five feet in length, supporting an engine of thirty-nine tons on twelve feet, would be in the same condition, nearly, as if loaded with twenty-six and a half tons at the centre, or fifty-three tons uniformly distributed. Engine No. 9 will throw forty-eight tons on twenty-one feet ten inches; or forty-four tons on fourteen feet nine inches, or a total load equivalent to about fifty-four tons uniformly distributed; therefore, spans twenty-five feet in length should be proportioned to carry at least five thousand pounds per lineal foot.

Isosceles trusses with short panels require distributing stringers, to distribute the weight borne by one pair of drivers over several apices. It is judicious, however, to assume six thousand pounds per lineal foot live load for fifteen feet, and three thousand pounds per lineal foot for the remainder of the span, for spans of forty to sixty feet, and to proportion the panel system accordingly.

In truss-bridges, with panels twelve to fifteen feet in length, the panel weight should vary from twenty-six to thirty tons. The uniformly distributed live load should not be less than three thousand pounds per lineal foot, for spans up to one hundred feet. Trains of merchandise may average nearly two thousand pounds per lineal foot: trains of locomotives and tenders, nearly three thousand pounds per lineal foot.

Allowing for differences (in loads) and for the effects of impact and high speeds, the following table will exhibit the average live loads and panel weights that may be safely assumed for different spans:—

Span.	Length of panel (about). Feet.	Panel weight per lineal foot.	Average load per lineal foot.	Excess of panel weight per foot over average load.	Total moving load. Tons.	REMARKS.
10	. . .	6,000	6,000	. . .	30	Solid girders.
12	. . .	6,000	6,000	. . .	36	" "
15	. . .	6,000	6,000	. . .	45	" "
20	. . .	5,500	5,500	. . .	55	" "
25	. . .	5,000	5,000	. . .	62.5	" "
30	15	6,000	3,500	2,500	71.2	Trussed or plate girders.
40	15	6,000	3,000	3,000	82.5	" " "
50	15	6,000	3,000	3,000	97.5	Trussed, plate, or lattice girders.
60	15	6,000	3,000	3,000	112.5	" " " "
75	12.6	5,000	3,000	2,000	125	Truss-bridge, single intersection.
100	$14\frac{2}{7}$	4,500	3,000	1,500	182	" " " "
125	14	4,500	2,900	1,600	192.5	" " " "
150	15	4,500	2,900	1,600	229.5	" " " "
200	$14\frac{2}{7}$	4,500	2,800	1,700	292	" " " "
250	$14\frac{3}{4}$	4,500	2,800	1,700	362	Truss bridge, double intersection.
300	15	4,500	2,700	1,800	413.5	" " " "
350	$14\frac{7}{12}$	4,500	2,600	1,900	469	Truss-bridge, double or trellis.
400	. . .	4,500	2,600	1,900	534	" " " "
450	. . .	4,500	2,500	2,000	577	" " " "
500	. . .	4,500	2,500	2,000	640	" " " "
550	. . .	4,500	2,400	2,100	675	" " " "

These proportions of panel weight may be slightly varied.

The uniformly distributed live load has been assumed sufficiently in excess of the actual weight of average trains, as previously recommended, to compensate for the destructive effects of impact, vibration, &c.

The long-span bridges, designed and erected by this Company, have been proportioned for a transient load equivalent to three thousand pounds per lineal foot; and in localities where high speeds may be maintained, the adoption of a less weight in the calculations, distributed as indicated, would not be considered judicious.

For bridges designed for lateral roads and light traffic, where light engines only are to be employed, a deduction of ten to twenty per cent. in live load and weight of engine may be admissible.

Roadway Bridges, City Bridges, Foot Bridges, Suspension Bridges.

Roadway bridges should be proportioned to support safely droves of cattle, or heavily-laden wagons, and when sidewalks are added, provision should be made to support the same when loaded with a crowd of people. The fearful tragedy at Dixon, Ill., gives force to this suggestion.

The minimum weight per square foot, on the floor appropriated to the roadway, should not be less than seventy-five pounds. For the footways, which may be packed with people, one hundred to one hundred and twenty-five pounds per square foot should be assumed as the maximum live load.

The floor joists and cross-girders, sustaining a panel length of twelve to fifteen feet, should be capable of supporting safely a weight of fifteen tons on that portion of roadway, and five tons on one panel length of each sidewalk six feet in width.

In city bridges, carrying street traffic, one hundred pounds per square foot of surface should be assumed as the minimum live load.

The girders and joists should be of sufficient strength to support this load, together with the dead weight of floor formation, with strains not exceeding one-half the elastic limit.

The destructive effects of vibration are increased, in roadway bridges, by irregularities in the roadway, the tread of animals, the measured step of infantry producing isochronous vibrations, and by numerous other causes incident to their use. For these reasons it is not considered advisable to assume a less factor of safety than that recommended for bridges designed for railways.

In the design and construction of foot bridges for public parks or private grounds, greater latitude is attainable. On crowded thoroughfares one hundred and twenty-five pounds per square foot may be required; while in quiet solitudes fifty pounds per superficial foot may afford ample strength.

Suspension bridges are generally constructed to span large openings, and the excessive weight required to support the loads here recommended for street and roadway traffic has, too frequently, induced their designers to assume live loads much lighter than prudence and careful investigation would seem to demand.

Examples are numerous in this country where thirty pounds per superficial foot of roadway has been taken to represent the live load, and under this load, and the weight of structure, the resulting strains in the cables are about one-fifth their ultimate powers of resistance.

We have never had the hardihood to design suspension bridges to carry less than sixty pounds per superficial foot, with a factor of six for safety.

Seventy pounds per square foot, with factor of safety of five, for best iron or steel wire cables, with ample provision for increased strength and stiffness of the floor system, seem the least that can be recommended, with due consideration for the safety and durability of such structures.

The Keystone Bridge Company, in designing structures, estimate for strains per square inch on the material, under the calculated maximum effects of the combined loads above stated, as follows:—

Best rerolled bridge iron, in tension, ten thousand pounds per square inch. Best chord iron, in compression, short column, eight thousand pounds per square inch. Columns, one-fourth the bending stress, as determined by quality of material, the ratio of length to diameter, and the mode of fixing. Cast iron, in compression, in short tubes, eight thousand to ten thousand pounds per square inch; compression, in long columns,—factor six, strength determined by empirical formula, or by experiment.

TENSION MEMBERS.—Members subjected to tensile stress should be of uniform strength throughout, presenting the greatest possible resistance to strains with the least weight and expenditure of material. The conditions are fulfilled—

First.—By the employment of square or round bars, with screw-ends enlarged by upsetting, so that the sectional area at the base of the screw-thread is equal to the area of the body of the bar.

Second.—Loops, formed on the ends of square bars by bending around the full section of the bar, and uniting the scarfed end to the body of the bar, exceed the strength of the bars, provided the reverse curvature of the loops is made with a radius of two to three feet, in proportion to the size of the bars.

Third.—Upset eye-bars, or rectangular bars with the enlarged ends made by compressing the iron, while hot, into moulds, by immense pressure, fulfill all the conditions of uniform strength. To obtain reliable eyes, it is necessary to upset the ends somewhat in excess of the required size, and, after reheating, reweld them under a steam-hammer, or by additional pressure.

The various methods employed to produce eye-bars of uniform strength had invariably proved unsuccessful, until Linville & Piper, in 1862, devised and demonstrated the success of their method of upsetting the ends.

Welded bars were found to be reliable only for seventy-five per cent. of the sectional area of the bar.

Howard and Ravenal rolled links, with the fibre impaired by the method of rolling, were not of much higher value. The usual process of upsetting by forging was unsuccessful, since frequent reheatings reduced the section at the junction with the heads.

By the Linville & Piper patent, eye-bars are made to shape under pressure in moulds, into which the heated iron is forced by immense pressure.

The head being slightly thickened,—say twenty per cent.,—the area of the connecting-pin should be greater than the area of the bar, and the semi-cylindrical surface-bearing should be equal to the sectional area of the bar. The sectional area outside of the pin-hole should exceed by twenty-five per cent. the area of the body of the bar. By increasing the thickness of the heads the diameter of the eye can, generally, be maintained at about one-half the width of the bar. The bearing-surface for the pin, as well as the resisting area at the eye, is more advantageously increased by thickening, than by increasing the width of, the heads.

The patent of Messrs. Linville & Piper cover the use of eye-bars for bridge and roof construction. They first introduced them in a bridge on the Junction Railway, and afterwards, in 1865, in the channel span of the Steubenville bridge.

The introduction of these forms, and the use of tubular struts, by decreasing the dead weight of bridges and increasing the effectiveness of the tensile and compression members and their connections, have worked a complete revolution in the method of bridge construction.

Compression Members.—The cylindrical form of strut or column is the best adapted, theoretically, to resist compressive force, applied vertically, in the direction of its axis. A hollow cylinder, of uniform thickness, is the only form of strut offering uniform resistance to flexture, transversely, in every direction, and affording the highest resistance with the least expenditure of material.

The great cost of lap or butt welded tubes led to the invention, by Messrs. Linville & Piper, of hollow posts, made by uniting together specially-rolled sections.

The addition of flanges, convenient in securing the edges, does not materially increase the lateral stiffness in the direction of the diameter taken midway between the flanges. The material in the flanges would therefore be more economically disposed by increasing the diameter or thickness of the shell.

This Company usually employ the octagonal form—in order to preserve greater symmetry in the proportions of columns—swelled towards the centre. By increasing the diameter at the centre, and separating the sections, greater resistance to flexure is obtained, and the openings between the sections allow the interior of the column to be repainted.

Patents were granted Linville & Piper in 1862 and 1865 for improvements in bridges, embracing wrought-iron columns, the use of upset chord links, and various important details of construction.

The first wrought-iron hollow columns of specially-rolled shapes were employed by Linville in 1861, in the construction of the iron bridge over the Schuylkill river, near the U. S. Arsenal, Philadelphia.

Since that time wrought-iron columns have rapidly superseded the use of cast iron in bridge construction.

Patents have since been granted to J. H. Linville for columns made of sections, united by transversely intersecting tie-bolts.

The material in the periphery is symmetrically disposed, and the tie-bolts effectually resist all tendency to collapse or bulge under pressure.

Experiments prove that columns united at intervals by transverse tie-bolts are stronger and more economical than riveted columns.

Mr. Piper's lately patented column is well adapted to bridge or architectural work requiring ornamental forms.

For horizontal or inclined compression members, the cylindrical form is inferior to rectangular sections. The weight of the cylindrical column or strut produces downward flexure. When cylindrical columns are employed as leaning struts, provision should be made to equalize their resistance to flexure.

The chord connections formed by interposing cast-iron blocks are open to objection. Upper chords should be continuous, and of one kind of material.

Chords and inclined struts, made up of beams, channels, plates, &c., are more generally adopted by the best builders.

Form and Arrangement of Details.—To secure the best results with the minimum of material, the details of a structure should be so designed as to render the connections of equal strength with the parts combined, and to direct the resulting stresses through the axial lines of the tension and compression members.

Every portion should be effective in supporting the loads, or in resisting wind pressure and lateral vibrations,—the strength of a composite structure being determined by the strength of its weakest part.

Uniformity of strains, with reference to the ultimate strength of the several members, should be carefully preserved.

By employing pin connections at the intersections of the chords, ties, and struts of a truss, the component and resultant strains are confined to directions coincident with the axis of the struts, ties, and chords.

The chord bars should be distributed on each side of each suspension diagonal or tie.

By this arrangement shorter pins may be employed, and all tendency to bend them may be obviated.

When all of the chord bars are disposed outside of the ties, the length of the connecting-pin, as well as the bending moment, is necessarily increased.

In the former disposition of the parts, the sectional area of the pin should be thirty-three per cent. more than the area of one chord bar, or one tie, if the section of the tie is greater than that of the chord bar.

In the latter arrangement, an increase of section is requisite to resist the moment of flexure due to the horizontal component of the stress on the tie, and the increased length of the pin.

The struts or posts may rest on the pins with circular bearings, or stand on the chords with flat bearings.

With circular bearings, transverse and diagonal strains in the struts must be resisted at the expense of nearly two-thirds of the effective strength of the strut.

The method adopted in our later improvements, by which pin connections are employed between the chords and ties, while the struts or posts bear with flat ends on the lower chords, and support the upper chords on flat end bearings, is most effective.

The deflection in a truss cannot produce any appreciable or injurious cross strain in wrought-iron struts so arranged. The combination is more solid and compact, and the effective strength of a column with flat bearings is secured without any increase in the cost of the combination.

Bearing surfaces in pin-holes, and elsewhere, should always be of such area as to resist, within the limit of prescribed strain per square inch, the weights they are required to support.

The weight of the moving load should be sustained directly from the pin connections at the lower apices, or placed directly over the pins of the upper apices. When transmitted through the chords, acting as a beam, increased transverse strength must be given to the chords.

By using transverse floor beams, supported directly on the chords, or on auxiliary beams placed parallel to the chords, the floor can be made more secure, at a slightly increased cost, than by the system of cross-girders and longitudinal stringers. When the latter method is employed, auxiliary stringers should be placed near the trusses. Long cross-ties, spaced about two feet between centres, should be arranged transversely on the stringers.

Longitudinal guard timbers, placed on top of the ties, may then be bolted through the ties and lower lines of stringers, thus effectually combining the whole. Such a combination, if planked over, would carry a train, in event of accident to wheels or axles, and, in most instances, protect the trusses from injury.

When members of a truss act both as struts and ties, provision should be made to prevent motion at, and consequent wearing of, the pin connections.

It is generally more economical and effective to employ counter-ties to resist the disturbing effects of accidental loads.

Upper lateral struts should bear against the chords in the line of longitudinal strain. If placed above the upper chords, transverse strain in the post will result.

Lateral and diagonal ties must be adjustable to insure perfect alignment of the trusses.

Upper chords can be made continuous, or be jointed over the posts. If joints are used they should be at the pin connections.

When jointed at each side of the posts, as by the method of short cast-iron joint-boxes, in combination with tubular wrought-iron sections, the chords are less rigid laterally, while the sections may be readily displaced by violent concussions, resulting in certain destruction to the entire span.

Every exterior part of a structure, as well as the interior of all rolled hollow members, should be readily accessible for cleansing and repainting, by which means, alone, the safety and durability of iron work can be insured.

The Keystone Bridge Company has, since its organization, advocated these views, and adhered to them in all construction designed by them, unless trammeled by specifications.

While they will faithfully adhere to plans and specifications provided by their patrons, and execute contracts for work according to the design prescribed, the details and proportions of work intrusted to them will, in all cases, be designed with reference to the greatest effectiveness and durability of all its parts; and in the execution of the work no efforts will be spared to attain that accuracy and perfection of workmanship of which their superior tools and appliances are a guarantee.

Adaptation to Locality and Service.—The adaptation of designs for bridges to the incidents of locality and scenery opens a wide field to the architect, for the display of refined taste and the production of æsthetic effects.

In subserving the requirements of railway traffic and roadway travel, the skillful engineer may combine economy and strength with beauty of design and correctness of proportion.

The grand structures that span our mighty rivers are beautiful by their apparent lightness and immense strength, resulting from a scientific disposition of materials.

The effect may be greatly enhanced by the selection of graceful and appropriate forms of truss, introducing ornamentation only to embellish the construction.

In the selection of a design, the locality as well as the service should be carefully considered.

For the deep ravine, the arch or the suspension bridge is generally most appropriate.

A series of graceful arches can be employed with the best effect for street bridges over wide rivers. The rigidity of arch bridges, owing to the absence of a tension chord, renders them particularly appropriate for traffic requiring heavy paved roadways.

In localities requiring spans of great length, suspension bridges with stiffened roadway may be successfully employed.

For street crossings, continuous beams, supported on columns located at the curb lines, are less expensive than single spans, and require less headway.

In parks or ornamental grounds, the light, graceful arch, the ornamental lattice or truss, or the varied forms of the suspension bridge, may, by skillful treatment, be made to harmonize with the surrounding scenery, and to enhance its beauty.

In the construction of railway bridges, utility and safety are the ruling considerations.

For this reason it is preferable to place the track on the upper chords whenever sufficient headway can be obtained for the purpose.

When the most economical length of span and depth of truss have been determined, an undergrade bridge should be employed, provided the requisite clearance can be obtained. Should the clear headway required for floods be insufficient, an overgrade bridge may then be employed, the track being placed near the level of the lower chords.

Overgrade bridges are more difficult to brace against wind pressure, and the trusses are more exposed than undergrade bridges to accident from passing trains.

High trusses, admitting overhead, lateral bracing, should be employed in spans over seventy-five feet or one hundred feet in length.

For spans shorter than seventy-five feet, better proportions are secured by employing low trusses, the upper chords being well stayed, laterally, by stay-braces footing into independent girders.

When the headway is limited, the track may be placed midway in the depth of the trusses or on the lower flanges, the cross-girders of rolled beams being secured by gussets and stays to the trusses.

For all the requirements of locality and service, this Company has matured designs, or will prepare such as cannot fail to meet the public wants.

They are not confined to any favorite design or mode of construction.

Their aim is to manufacture and adapt their work to the views of their patrons.

While the plans and details, that have been matured and tested satisfactorily by years of severe trial, can be recommended with confidence to engineers and the public, any changes that may be suggested will be duly considered, and modifications from our standard forms will be made, when desired.

A plan and profile of the locality, with precise information as to the location, capacity, and object of a proposed structure, will generally enable us to prepare an approximate estimate and acceptable design.

Specifications.—The bridges constructed by the Keystone Bridge Company conform to these general specifications.

Structures are proportioned to sustain rolling loads, and panel weights specified in the tables, unless otherwise ordered. Tensile strains resulting from these loads, together with the dead weight of the superstructure, shall not exceed ten thousand pounds per square inch of sectional area.

Strains in compression shall be varied in proportion to the ratio of length to diameter of columns and chords, by Gordon's formulæ, so as to afford the same factor of safety, referred to the elastic limit, as in the tension members.

The iron employed in tension shall be soft, fibrous iron, specially manufactured, by repiling and rerolling refined bars, in order to insure the requisite uniformity and toughness for first-class bridge work.

Beams, channels, and plates to be equal to any other in the market.

Lower chords and (when desired) suspension bars will be our patent weldless chord bars, or bars with upset eyes.

Ties and counter-ties, laterals and suspension bolts, will be made without welds, excepting in forming scarf-welded loops, in which the weld receives only one-half of the strain sustained by the bolt.

Screw-threads will be enlarged by upsetting, so that the area of the screw end, clear of the thread, will equal the area of the bar.

All abutting joints will be planed or turned, and all pin-holes accurately bored, so that no error in length between pin-holes shall exceed one sixty-fourth of an inch.

Pins shall accurately fit the holes.

In riveted work all abutting joints shall be true, and all edges neatly dressed.

Rivet-holes shall be accurately spaced and truly opposite.

Rivets shall be made of the best rivet iron, and shall be duly proportioned to insure the strongest work. They shall be driven to completely fill the holes, and shall have full heads.

All iron-work shall have one coat of suitable paint and oil at our works.

All turned or planed work exposed shall be protected with white lead and tallow before shipment.

Parties procuring work of us have the privilege of making any tests they require on material and finished work, within reasonable limits, to satisfy themselves of the accuracy and general quality of workmanship and materials.

The materials will all be manufactured with special reference to the uses to which they are applied, and all workmanship will be of the best quality found in first-class bridge work.

The deflection of structures depends upon the ratio of depth to length of span, and the strain per square inch on the material.

With the usual proportions, our bridges deflect less than one inch per one hundred feet of span under trains of locomotives moving at high speeds, and recover their original camber after the removal of the weight.

Floor system will be arranged with stringers and cross-ties, transverse floor-beams, or with extra stringers, long ties, and guards, as may be stipulated in orders for work.

Counter-bracing.—The action of counter-bracing, in a truss under the effects of a uniformly distributed stationary load and a moving load of uniform density, may be exhibited to the eye by a simple arithmetical method.

The reaction of the supports is together equal to the aggregate weight of fixed and partial loads.

The reaction of each support is equal to one-half the uniformly distributed dead load.

The reaction of each support, due to the partial load, is equal to the load multiplied by the distance of its centre of gravity from the remote support, and divided by the distance between the supports.

The reactions of the supports having been determined as above, by the principle of the lever, the resulting strains in every portion of the truss can be found by resolving the forces towards the centre, deducting, as the operation progresses, the weights borne at each apex until a point be found at which there is no vertical strain. At this point the strains of compression in the upper chord and of tension in the lower chord are greatest, and they meet and balance, showing that the system is in equilibrium. The portions of the uniform and partial moving load, on each side of this point, do not pass the point of no vertical strain, but are transmitted to the nearest support.

Ties and counter-ties in the same parallelogram or panel cannot both act at the same time, unless an initial stress be given to the counter-tie. The elongation of one diagonal under tensile stress relieves the tension in the other.

These propositions may be demonstrated by a simple arithmetical method, as follows:—Let figure 1, plate 10, be a simple truss of ten equal panels. Assuming that it is uniformly loaded with four tons, supported at each of the lower apices, the reaction of each support will be twenty tons,—eighteen tons passing through the end verticals, and two tons being transmitted directly to the supports by the track-stringers.

Resolving the forces towards the centre and indicating the strains in terms of the vertical weight, remembering to deduct the weight of one panel or four tons at each lower apex—the point of equilibrium, and no vertical strain will be found at the centre. The actual strains on the ties are found by multiplying the vertical effects by the secant of the angle of inclination of the ties, and the actual effects on the chords by multiplying the vertical components by the tangent of the angle made by the tie with the vertical.

The counter-ties are not brought into action under a uniformly distributed load.

Let figure 2, plate 10, be a similar truss, devoid of weight.

If a weight $W_1 =$ ten tons be suspended at the first lower apex, nine tons will be transmitted to the right support and one ton to the left support,—the strains being indicated on the diagram.

If another weight $W_2 =$ ten tons be suspended at the second apex, the reactions are respectively $\frac{3}{20} \times$ twenty tons = three tons on the left support, and $\frac{17}{20} \times$ twenty tons = seventeen tons on the right support.

The resulting strains are indicated in figure 3, in terms of the vertical components. The strains in the lower chords and ties, together, balance at the point of no vertical strain. It may, in the same manner, be shown that with W_1 applied at the first apex, $\frac{1}{10}$ of this load goes to the remote support; with W_2 applied in addition to the second apex, $\frac{3}{10}$ of one panel weight goes to the remote support; with W_3 applied in addition at the third apex, $\frac{6}{10}$ of one panel weight goes to the remote support; and so on in a simple series, increasing by the addition of two, three, four, five, &c. to the numerators of the fractional co-efficients whose denominator is the number of panels.

In figure 4, plate 10, the effects of the uniform load of four tons at each apex is combined with the effect of $W_1 =$ ten tons applied at the first apex. The reactions of the end verticals being found, as before, the resulting strains are indicated in terms of the vertical components.

It is apparent that no counter-tie is required in this figure, the weight at the centre being precisely balanced. A counter-tie, adjacent to the centre, cannot be brought into action until the centre vertical, with the *weight of half a panel of the uniform load*, has been lifted.

In figure 5, plate 10, an additional weight of ten tons is applied at the second apex. Total weight, sixty tons. The effects will be as indicated.

To make up the total reaction on the right support, seventeen tons of the uniform load and the entire partial load of twenty tons go to this support.

The remaining diagrams exhibit the effects when the partial loads are added successively to the remaining apices.

If $W =$ the uniformly distributed load on one panel,

$W_1 =$ the moving load of uniform density on one panel.

The co-efficients for the end diagonals, for uniform load, will be half the number of panels less one-half, or the number of panels less one divided by two, and decreasing from the end by deducting one panel weight from each successive diagonal tie.

The weight on the ties that meet at the centre will be one-half panel to each.

The fractional co-efficients for the ties for a load moving from the left until it covers the entire bridge are, for numerators, 1, 3, 6, 10, 15, 21, 28, &c., increasing from unity by regular additions of 2, 3, &c., the denominators being the number of panels.

In a truss of ten equal panels, with height equal length of one panel, or one-tenth the span, the maximum strains may be found as follows:—

$R =$ secant of tie angle $= \frac{\text{diagonal one panel}}{\text{vertical}} = \frac{\sqrt{10^2 + 10^2}}{10} = 1.414.$

$S =$ tangent of tie angle $= \frac{\text{base one panel}}{\text{vertical}} = \frac{10}{10} = 1.$

$W =$ four tons.

$W_1 =$ ten tons.

No. of tie.	FORMULÆ.	Vertical effect.	Resultant strain on tie.	See figure, (Plate 10,)
1	$(\frac{45}{10} W_1 + \frac{9}{2} W) R.$	63.00	89.08	No. 12
2	$(\frac{36}{10} W_1 + \frac{7}{2} W) R.$	50.00	70.70	" 11
3	$(\frac{28}{10} W_1 + \frac{5}{2} W) R.$	38.00	53.73	" 10
4	$(\frac{21}{10} W_1 + \frac{3}{2} W) R.$	27.00	38.18	" 9
5	$(\frac{15}{10} W_1 + \frac{1}{2} W) R.$	17.00	24.04	" 8
6	$(\frac{10}{10} W_1 - \frac{1}{2} W) R.$	8.00	11.31	" 7
7	$(\frac{6}{10} W_1 - \frac{3}{2} W) R.$	0.00	. . .	" 6

HINTS TO PARTIES ORDERING BRIDGES.

When ordering bridges or soliciting proposals or designs, parties should furnish us the following information, if practicable:—

Distance from centre to centre of piers.

Distance in clear between piers.

Thickness of piers and width of bridge-seats on abutments.

Length of piers and bridge-seats on abutments.

Distance from base of rail to top of masonry.

Angle made by centre line of piers with axis of bridge.

Distance from grade to high and low water.

Depth of water, mud, &c. in river.

Kind of bottom in river,—mud, gravel, sand, or rock, &c.

Description of bridge required, whether for railway or highway, single or double track.

State whether sidewalks are required.

Whether track is required on upper or lower chords.

If the locality is occupied by an existing structure, give description of same.

State the nearest point to which material can be transported by rail or water.

For pivot bridges give clear openings, diameter of pivot-pier, distance from grade to top of masonry and high water.

Name the loads per lineal foot for railway bridges, or per superficial foot of floor for roadway bridges, that the bridge will be required to carry in addition to weight of structure.

Railway companies, who have constant use for timber on their lines, will find it more economical to provide the lumber for false-works and scaffolding.

They may also furnish the stringers and cross-ties, and place the same at reduced cost and remove existing wooden bridges. If they desire to do this they should so advise us.

By reference to the following descriptions and plates, a design may be selected, or some general idea of the class of structure desired may be given us.

The President of this Company may be consulted as to the location and the designs and specifications for important works.

Communications, in reference to bridges, roofs, iron buildings, rolling-mills, or any work in our line, may be addressed to either of our offices, as follows:—

To J. H. Linville, President, 426 Walnut street, Philadelphia.
To J. L. Piper, General Manager, Pittsburgh, Pa.
Or Walter Katté, Engineer Keystone Bridge Company, 211 Washington avenue, St. Louis, Mo.

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DESCRIPTION OF THE PLATES.

Division A.—Solid Girders.

Plate 1, figures 1, 2, 3.—These bridges are of solid rolled beams for spans from ten to twenty feet.

They are especially adapted for farm-road crossings under railways.

They will be shipped ready for erection, and can be placed in position by the trackmen or road carpenters.

Division B.—Trussed Girders.

Plate 1, figures 4, 5, 6.—These girders are adapted to spans of twenty feet to sixty feet. The upper chords are composed of rolled beams or channels, to which a top plate is riveted to increase the lateral resistance.

The vertical struts are made of tubular post iron or rolled beams.

The lower chords and ties are composed of weldless links joined by connecting pins.

Adjustable counter-bracing and lateral and diagonal bracing render these girders rigid and prevent lateral vibration. They are the most economical form of girder for limited spans.

Division C.—Plate Girders.

Plate 1, figures 7, 8, 9.—Plate girders are the most rigid form of girders, and can be used with advantage in spans from twenty feet to sixty feet, and upwards.

Girders sixty feet in length may be shipped complete, ready to be placed in position.

These girders are more expensive than trussed girders, but give the highest satisfaction on roads where heavy traffic and high speeds prevail.

We build these bridges with either three or four girders for double track.

The floor beams may be of wood or iron.

When the headway is limited, we use rolled beams for cross-beams, supporting them on the lower flanges, and uniting them to the trusses by gussets or angle iron.

Rigid lateral and diagonal bracing is introduced when desired.

DIVISION D.—DECK BRIDGES, SINGLE INTERSECTION TRUSS.

Plate 2, figures 1 to 12.—These bridges, illustrated in elevation, plan, section, and detail, are made with vertical end posts, or with the upper chord supported on bolster and pier plates, resting on the stone bridge-seats.

The upper chords are continuous and exclusively of wrought iron, being composed of rolled beams, channels, and plates, the underside being left open to admit of repainting.

The posts are hollow, rolled columns, also left open to facilitate inspection and repainting of the interior.

Unless repainted every few years, hollow columns will rapidly deteriorate by oxidation.

The lower chords are weldless eye-bars. The diagonal ties either weldless bars or square bars, with loops formed by long scarf welds, subjected to only one-half the strain that is resisted by the ties. Counter-ties and laterals are adjustable. Pin connections are used in upper and lower chords. The track is supported on long cross-ties, resting on heavy longitudinal stringers, which are carried on transverse rolled beams placed over the posts. No transverse strains can occur in the tension or compression members. These bridges can be adapted to any span or depth of truss required, and may be used for double track, with either two or three trusses. By increasing the section of the upper chords, transverse floor timbers of wood can be used instead of the system of track shown in the plate.

The lateral struts are placed opposite the centre lines of the chords—their normal position, obviating any undue strains on the posts, and rendering the lateral and diagonal bracing independent of the floor girders.

DIVISION E.—THROUGH OR OVERGRADE BRIDGES, SINGLE INTERSECTION.

Plate 3.—Figures 1, 2, 3, and 4 illustrate a description of truss now generally adopted for spans over seventy-five feet. Figures 5, 6, 7, 8, 9, 10, and 11 illustrate a design adapted to shorter spans.

In spans over seventy-five feet the trusses are made of sufficient height to admit upper lateral bracing.

These bridges have all our improvements—cylindrical hollow columns, wrought-iron upper chords, weldless chord links, pin connections, adjustable counters, suspended cross-girders, and improved safety floors.

When desired, longitudinal iron beams are placed between the chords to support transverse floor beams.

The low trusses have stay-braces, abutting against independent transverse beams, and are consequently free from vibrations caused by the deflection of the cross-girders.

The leaning end posts are connected by suitable ribs to the pin connections with the upper chords, obviating the strains occurring at this point in the usual form of rigid connections.

The caps and bases of the posts are made of *wrought* or cast iron, as may be specified.

DIVISION F.

Plate 4.—Through or overgrade bridges one hundred and fifty to two hundred and fifty feet spans, and upwards.

This general design, with slight modifications, may be used for deck or undergrade spans.

Figures 1, 2, 3, and 4 show the general design of truss in elevation, plan, and section. Figures 5 to 13 are details of the posts, chords, and connections.

A peculiarity in this design is the new method of combining columns having flat ends with weldless chords and pin connections.

Figures 10 and 12 show the connection between the chords and posts. The lower chords are brought compactly together, the posts resting on the same, by means of a flat bearing-plate. No ribs are required, the pins are reduced to their minimum length, and the strength of the columns is nearly doubled, without decreasing the elasticity of the structure. At the upper chord short bearing-pieces are introduced to support the pin, at short intervals, and afford a bearing for the caps of the post. These details are superior in economy and efficiency to any others now employed.

Spans over one hundred and fifty feet have knee-bracing at all posts, to resist the effects of wind pressure.

DIVISION G.—PIVOT OR DRAW BRIDGES.

Plate 5.—Figure 1 is a side elevation; figures 2 and 3, plan of lower and upper chords; figures 4 and 5, end elevation and section at the half-span, and figure 6 an elevation at centre of bridge. Figures 7 and 8 show the central cone, drum, track, and rotating gear, operated by an engine attached to the drum. Figure 9 shows the wedges which give firm supports to the ends of the trusses when elevated by the hydraulic lifts. The machinery of the turning and elevating gearing is so perfect that one man controls the turning and elevating apparatus at will, by a system of levers.

The longest span pivot bridges in the country now in successful operation are controlled with ease and certainty by the apparatus illustrated.

Various forms of improved pivot centres are now employed by this Company. For shorter spans a centre similar to that used for turn-tables, illustrated on plate 9, is generally employed.

Plans for railway or roadway bridges, of any span, operated by power or by hand, furnished on application. Engines placed overhead or beneath the floor, as desired.

The great pivot bridges at Dubuque, Keokuk, Kansas City, Chicago, Cleveland, Middletown, Philadelphia, and many others, have been constructed by this Company, and give great satisfaction.

DIVISION H.—LONG-SPAN BRIDGES, 250 TO 500 FEET AND UPWARDS.

Plate 6.—Figures 1, 2, and 3 illustrate the style of bridges so successfully employed over the Ohio river, at Bellaire, Parkersburg, and Cincinnati;—the latter span of four hundred and twenty feet is the longest span of iron truss-bridge on this continent.

The trusses are double, rendering them much more effective than single trusses, to resist wind pressure.

This Company has been the *pioneer* in the construction of long-span railway bridges, and the invariable success that has attended their efforts in this direction has gained for them a prestige enjoyed by no other company.

We are prepared to execute spans of truss-bridge or arches, in iron or steel, for spans up to six hundred feet, and guarantee satisfactory results. Over deep ravines or rivers, the spans can be erected without scaffolding.

DIVISION I.—SUSPENSION BRIDGES, STREET AND PARK BRIDGES.

Plate 7.—Figures 1, 2, and 3 show the usual form of wire suspension bridge. These bridges are adapted to roadway traffic, in spans of any extent up to one thousand six hundred feet. The towers may be either of iron or stone.

Iron stiffening-trusses are introduced to prevent undulation.

Sidewalk trusses are employed to serve the double purpose of stiffening-trusses and railings.

The cables are made of iron or steel wire, or of iron or steel links, according to span required.

We prefer the cables made of flat links, vertical ties, and stiffening-trusses. For railway bridges, a peculiar and effective arrangement of stiffening-trusses is employed, rendering these bridges as rigid as a truss-bridge.

Figures 4 and 5 illustrate a usual and elegant form of wrought-iron or steel arch adapted to street traffic of large cities. These designs can be varied to exhibit any degree of elegance and ornament suited to the locality.

Whenever it is admissible, the arch form, from its elegance, should be preferred for the avenues of approach to cities.

DIVISION J.—IRON ROOF TRUSSES.

Plate 8.—Figures 1 and 2 are diagrams of the usual form of iron roof trusses.

These forms are varied by us indefinitely, to adapt them to circumstances. They may be curved or hipped.

The details are perfect. Figure 3 shows the heel-block and connection, with the rolled deck-beam used as a principal.

Figures 4 and 5, the struts of channel-bars or T iron, and the connections with the ties and principal.

Figure 6 shows the connection at the hip.

Figure 7 illustrates the usual form of rib employed for large spans up to three hundred feet, suitable for terminal passenger depots, &c.

The curvature and ornamentation of these designs can be modified according to circumstances.

We are extensively engaged in the construction of shops, depots, and rolling-mills, steel works and furnace buildings, with iron framework and iron roofs.

Wooden roofs and heavy framing of wooden brides, trestle-work, &c., a specialty.

DIVISION L.

Plate 11.—This is a highly ornamental structure, with 16-foot sidewalks and 68-foot roadway, designed for the bridge over the Schuylkill river at Girard avenue, Philadelphia, to accommodate the travel to Fairmount Park.

The roadway consists of granite paving, laid on iron quarter-inch buckle plates, supported on transverse beams of rolled iron.

The sidewalks paved with slate flagging, ornamented with borders of encaustic tiles.

The trusses are ornamented, and the railings, lamps, guard-railings, &c., are of elaborate design.

The bridge was designed to carry one hundred pounds per superficial foot of floor, with factor of six for safety.

Masonry of granite, neatly cut.

Piers founded on the solid rock, without concrete.

A bridge constructed according to this design may be made of any width or with any desired ornamentation.

TURN-TABLES.

Plate No. 9.—The Keystone Bridge Company's wrought-iron turn-tables for railroads have been brought to the highest degree of perfection. By the use of the improved steel-cone centre, invented and patented by John L. Piper, General Manager, he effects certain improvements over other anti-friction centres in use. The cones of the "Piper centre" are longer, give more bearing, and cannot be displaced.

They are kept in true radial line by steel spindles, which bear at the outer ends against a steel ring, greatly reducing the friction.

These centres are used also in some of our pivot bridges.

The turn-tables are entirely of wrought iron, in the best form of plated beams. They are thoroughly trussed, both laterally and diagonally, and are provided with trailing wheels carried by wrought-iron beams. They are adjustable at the centre. The exemption from risk of fracture so frequently occurring in cast-iron tables—their adaptation to any size or depth of existing pit, without expense or delay for new patterns—their cheapness, strength, and durability—render them greatly superior to any other turn-table offered to the public.

The leading railways are using them to the exclusion of other forms.

Wherever they have been tested, they give unbounded satisfaction.

Plans, lithographic views, estimates, &c., furnished on application, and new tables, adapted to diameters and depth of pits, supplied on short notice.

PLATE 12.

I BEAMS.		[CHANNEL BARS.		DECK BEAMS.		WROUGHT-IRON COLUMNS.		ANGLE (L) IRONS.		TEE (T) IRONS.		+ IRONS.	
Depth of beam. Inches.	Range of weights per lineal foot. Pounds.	Depth of beam. Inches.	Range of weights per lineal foot. Pounds.	Depth of beam. Inches.	Weight per lineal foot. Pounds.	Diameter of column. Inches.	Range of weight per lineal foot. Pounds.	Size of L. Inches.	Range of weights per lineal foot. Pounds.	Size of T. Inches.	Range of weights per lineal foot. Pounds.	Size of +. Inches.	Weight per lineal foot. Pounds.
15	50 to 80	. . .	. . . . .	. .	. . .	12	50 to 200	4 × 4	11 to 15	6½ × 3½	38	4 × 4	14¼
12	38 “ 65	12	30 to 45	. .	. . .	10	45 “ 150	3½ × 3½	9 “ 12	4½ × 3⅛	24	3½ × 3½	12¼
10	30 “ 38	10	20 “ 40	. .	. . .	8	40 “ 105	3¼ × 3¼	8 “ 10	4½ × 2⅝	17½	3 × 3	9¼
9	23½ “ 30	9	18 “ 36	9	23⅓	6	24 “ 55	3 × 3	7 “ 9	5 × 3	11 to 17	2½ × 2½	5¾
8	21½ “ 27	8	15 “ 23	8	21½	4	17 “ 38	2½ × 2½	5 “ 7	5 × 2½	11 “ 16	2 × 2	3¾
7	16⅔ “ 20	7	13½ “ 21	7	15½	. .	. . . . .	2¼ × 2¼	4 “ 6	4½ × 3½	13½ “ 17	1½ × 1½	2
6	13.5 “ 16	6	11 “ 16	. .	. . .	. .	. . . . .	2 × 2	3 “ 4½	4½ × 3½	13	. . . . .	. . . . .
5	12 “ 15	5	9 “ 14	. .	. . .	. .	. . . . .	1¾ × 1¾	2 “ 2½	4 × 2	6½ “ 10	. . . . .	. . . . .
4	08¾ “ 10¾	4¾	7 “ 13	. .	. . .	. .	. . . . .	1½ × 1½	1½ “ 2	3½ × 3	10 “ 13½	. . . . .	. . . . .
. .	. . . . . .	3	4¾ “ 7¼	. .	. . .	. .	. . . . .	1¼ × 1¼	1¼ “ 2	3½ × 3½	11	. . . . .	. . . . .
. .	. . . . . .	2	2.9	. .	. . .	. .	. . . . .	1⅛ × 1⅛	1	3 × 3½	10 “ 14½	. . . . .	. . . . .
. .	. . . . . .	. .	. . . . . .	. .	. . .	. .	. . . . .	1 × 1	½	2½ × 1¼	2¼ “ 4¼	. . . . .	. . . . .
. .	. . . . . .	. .	. . . . . .	. .	. . .	. .	. . . . .	. . . . .	. . . . .	$1\frac{3}{16} \times 1\frac{3}{16}$	1¾	. . . . .	. . . . .

All the above shapes are rolled by Carnegie, Kloman & Co., whose works are in immediate contiguity to those of the Keystone Bridge Company. These and other special designs will be supplied by us, fitted ready for use in buildings, bridges, or other structures, at rates as low as offered by any other responsible parties.

IRON BRIDGES CONSTRUCTED BY THE KEYSTONE BRIDGE COMPANY.

NAME OF COMPANY.	LOCATION.	Kind of bridge.	Number of spans.	Length of spans.		Single or double track.	Length of single track.	
				Ft.	In.		Ft.	In.
Pennsylvania Railroad Extension,	Monongahela, channel span,	Through.	1	262	0	Double.	524	0
“ “ “	“ east span,	Deck.	1	182	0	“	364	0
“ “ “	Bailey's Coal Works,	Half-through.	1	86	8	“	173	4
Pittsburgh, Cincinnati and St. Louis Railway,	Steubenville,	Deck.	3	206	5	Single.	619	3
“ “ “ “	“	“	4	232	1½	“	928	6
“ “ “ “	“ channel span,	Through.	1	319	0	“	319	0
“ “ “ “	Saw Mill run,	Deck.	3	137	0	Double.	822	0
“ “ “ “	“ “ “	“	2	115	6	“	231	0
“ “ “ “	Whitewater,	“	1	178	0	Single.	178	0
“ “ “ “	Dayton,	Through.	1	101	9½	“	101	9½
North Missouri Railway,	Middle Fork creek,	“	1	130	0	“	130	0
Chicago, Alton and St. Louis Railway,	Paine creek,	“	1	102	6	“	102	6
Mississippi River Bridge Company,	Louisiana bridge,	“	7	157	0	“	1,099	0
Illinois Central Railroad,	Catfish No. 1,	“	1	104	10½	“	104	10½
Cleveland, Mt. Vernon and Delaware Railroad,	Mt. Vernon,	“	2	153	6	“	307	0
Pittsburgh and Cleveland Railroad,	Yellow creek,	“	1	154	0	“	154	0
Michigan Southern and Northern Indiana Railroad,	Swan's creek,	“	1	115	0	Double.	230	0
Central Railroad of New Jersey,	Point of Rocks,	“	1	136	10½	Triple.	410	7½
Chicago and North-western Railroad,	Clinton,	“	2	147	0	Single.	294	0
Sharpsburg and Lawrenceville Bridge Company,	Sharpsburg, roadway,	“	5	179	6	“	897	6
North Missouri Railroad,	Moline creek,	Deck.	1	81	0½	“	81	0½
Philadelphia, Wilmington and Baltimore Railroad,	North Christiana creek,	“	1	82	6	Double.	165	0
Coal Road Branch of Pennsylvania Railroad,	Tinker run, Irwin Station,	“	2	63 59	9 0	Single.	122	9
Allegheny Valley Railroad,	Kiskiminetas,	“	5	142	10	Double.	1,428	6
“ “ “	Pine creek,	“	1	88	9	Single.	88	9
“ “ “	Cowanchannock,	“	1	88	9	“	88	9
“ “ “	Crooked creek,	“	2	104	2	“	208	4
Pittsburgh, Washington and Baltimore Railroad	Soho, span 2,	Half-through.	1	52	0	Double.	104	0
Little Miami, Columbus and Xenia Railroad,	Cæsar creek,	“	2	85 71	0 8	Single.	156	8
Pacific Railroad of Missouri,	Taylor creek,	“	1	77	6	“	77	6
Thomas Iron Works,	No. 1,	“	1	42	8	“	42	8
“ “ “	No. 2,	“	1	92	0	“	92	0
“ “ “	Rockaway,	“	1	78	11	“	78	11
Lehigh and Susquehanna Railroad,	Delaware river, Easton,	Deck.	6	163	9	“	982	7
“ “ “	Lehigh river, Spans 1 and 3,	“	2	159	4	Single.	668	8
“ “ “	“ “ Span 2,	Through.	1	175	0	Double.		
Baltimore and Ohio Railroad,	Bellaire,	Deck.	4	205	0	Single.	820	0
“ “ “	“	Through.	1	235	0	“	235	0
“ “ “	“	“	1	342	0	“	342	0
“ “ “	Parkersburg,	Deck.	4	205	0	“	820	0
“ “ “	“	Through.	2	342	0	“	684	0
“ “ “	Lockport, Ohio,	“	1	94	0	“	94	0
Pittsburgh, Fort Wayne and Chicago Railroad,	Bridge No. 85,	“	1	104	0	“	104	0
“ “ “ “	“ No. 36,	“	1	104	0	“	104	0
“ “ “ “	Swan's bridge,	“	1	124	2	“	124	2
“ “ “ “	Fort Wayne canal,	Half-through.	1	72	0	“	72	0
“ “ “ “	St. Mary's,	“	2	73	0	Double.	292	0
“ “ “ “	Plymouth,	“	2	61	4	Single.	122	8

Iron Bridges Constructed by the Keystone Bridge Company.—Continued.

NAME OF COMPANY.	LOCATION.	Kind of bridge.	Number of spans.	Length of spans Ft.	Length of spans In.	Single or double track.	Length of single track Ft.	Length of single track In.
Pittsburgh, Fort Wayne and Chicago Railroad,	Bridge No. 33, Wooster, Ohio,	Half-through.	2	73	8	Double.	294	8
“ “ “ “ “	Canton, Ohio,	“	1	74	0	Single.	74	0
“ “ “ “ “	Bridge No. 8,	“	1	79	4	Double.	158	8
“ “ “ “ “	Loudenville,	Deck.	2	105	3	Single.	210	6
“ “ “ “ “	Kaler's,	“	1	84	0	“	84	0
“ “ “ “ “	Beaver river,	“	3	136	6	Double.	819	0
“ “ “ “ “	“ “	“	2	68	2	“	272	8
“ “ “ “ “	Franklin,	“	2	64	0	Single.	128	0
“ “ “ “ “	Nevada,	“	1	86	8	“	86	8
“ “ “ “ “	Upper Sandusky,	“	2	108	9	“	217	6
Northern Central Railway,	Dauphin, Spans 9 and 14,	Through.	2	206	0½	“	412	1
“ “ “	Reservoir, Baltimore,	“	1	156	4½	Double.	312	9
“ “ “	North avenue, Baltimore,	Half-through.	2	107	6	“	430	0
“ “ “	Hominy Mill, Baltimore,	“	1	104	9½	“	209	7
“ “ “	White Hall,	“	1	74	0	“	148	0
“ “ “	Bridge No. 6,	“	1	63	0	“	126	0
“ “ “	Bridge No. 113,	Deck.	1	65	0	“	130	0
“ “ “	Gunpowder,	Through.	1	161	9	“	323	6
“ “ “	Burns' bridge,	Half-through.	1	79	2	“	158	4
“ “ “	Charles street, Baltimore,	“	1	124	3	“	248	6
West Chester and Philadelphia Railroad,	Mayland's creek, Philadelphia,	Deck.	1	128	8	Single.	128	8
Connecting Railway,	Thirty-seventh and Poplar streets, Philadelphia,	Half-through.	3	1. 78 2. 21	3 6	Double.	242	6
“ “	Girard avenue, Philadelphia,	“	3	1. 86 2. 32	9½ 9½	“	302	9
“ “	Broad street, Philadelphia,	“	3	1. 73 2. 34	6 6	“	283	0
“ “	Eleventh and Germantown road, Philadelphia,	“	1	1. 88	6	“	177	0
“ “	York avenue, Philadelphia,	“	1	72	1	“	144	0
“ “	Richmond Branch Railroad,	“	1	52	9	“	105	6
“ “	Schuylkill river,	Deck.	1	262	0	“	524	0
Chicago City,	Madison street, roadway,	Half-through.	1	85	6	“	171	0
“ “	Randolph street, “	“	1	80	0	“	160	0
“ “	Lake street, “	“	1	77	3	“	154	6
Allegheny City,	Ohio street, “	“	1	64	0	“	128	0
Chicago City,	Adams street,	Through.	1 1 1 1	104 73 68 54	0 0 0 0	“	913	0
“ “	“ “ pivot span,	“	1	157	6			
“ “	State street,	Half-through.	4	76	0	“	1,116	0
“ “	“ “	Deck.	2	36	0			
“ “	“ “ pivot span,	Through.	1	182	0			
“ “	North Water and Wells streets,	Half-through.	1	82	6	“	165	0
“ “	North Clark street,	“	1	77	0	“	154	0
Terre Haute and Indianapolis Railroad,	Wabash river,	Through.	4	163	0	Single.	815	0
“ “ “ “	“ “ pivot,	“	1	163	0	“		
Dubuque and Dunleith Bridge Company,	Dubuque, shore spans,	“	8	93	0	“	744	0
“ “ “ “	“ river “	“	6	2. 247 4. 222	0 0	“	1,382	0

Iron Bridges Constructed by the Keystone Bridge Company.—Continued.

NAME OF COMPANY.	LOCATION.	Kind of bridge.	Number of spans.	Length of spans.		Single or double track.	Length of single track.	
				Ft.	In.		Ft.	In.
Dubuque and Dunleith Bridge Company,	Dubuque, river, pivot,	Through.	1	356	6	Single.	356	6
Baltimore and Potomac Railroad,	Long bridge, Washington, pivot,	Deck.	1	123	2	Double.	246	4
Pittsburgh, Fort Wayne and Chicago Railroad,	Chicago, pivot,	Through.	1	225	0	Single.	225	0
Marietta and Cincinnati Railroad,	Muskingum, near Harmar, pivot,	"	1	133	11	"	133	11
Cuyahoga,	Cleveland, Ohio, pivot,	"	1	306	0	"	306	0
Kansas City,	Kansas City, pivot,	"	1	359	4	"	359	4
New Orleans, Mobile and Chattanooga Railroad,	Nos. 1, 2, 3, pivot,	"	3	191	0	"	573	0
" " " "	No. 4, pivot,	"	1	235	0	"	235	0
Keokuk and Hamilton Bridge,	Keokuk,	"	4	161	7	Double.	4,018	0
" " "	"	"	3	159	9			
" " "	"	"	2	253	6			
" " "	" pivot,	"	1	376	5			
New Haven, Middletown and Willimantic Railroad,	Middletown, Connecticut,	"	2	54	0	Single.	1,232	0
" " " "	" "	"	4	206	0			
" " " "	" " pivot,	"	1	300	0			
New Jersey Railroad and Transportation Company,	Newark, New Jersey,	"	2	1. 95 1. 115	0 6	Double.	847	0
" " " "	" " pivot,	"	1	213	0			
Newport and Cincinnati Bridge Company,	Newport, market space,	Half-through.	1	56	0	Single.	5,924	6
" " " "	" triangular trusses,	"	3	1. 41 1. 45 1. 44	8 0 4	1 Railroad. " 2 Roadway.		
" " " "	River spans 5 and 6,	Through.	2	200	0	"		
" " " "	" " 4,	"	1	257	1	"		
" " " "	" " 3,	"	1	237	0	"		
" " " "	" " 2,	"	1	415	0	"		
" " " "	" " 1,	"	1	133	0	"		
" " " "	Shore spans,	Half-through.	2	93	3	"		
" " " "	" "	Through.	1	116	9	Single.		
" " " "	" "	Deck	7	79	11	"		
" " " "	" " plate girder,	"	2	1. 53 1. 43	6 3	Double.		
Illinois and St. Louis Bridge,	St. Louis,	....	2 1	515 520	0 0	"	3,100	0
Philadelphia,	Fairmount bridge,	....	1	348	0	"	696	6
"	" " approaches,	....	..	...		"	1,290	0
Junction Railway, Philadelphia,	Mayland's creek,	Through.	1	132	0	"	264	0
Pennsylvania Railroad,	Canal, Middletown,	Half-through.	1	79	6	"	159	0
" "	Coatesville,	Deck.	6	140	0	"	1,680	0
" "	Big Conestoga,	"	2	140	0	"	560	0
" "	Thirty-fifth street, Philadelphia,	Half-through.	1	74	0	"	148	0
" "	Columbia,	Through.	2	96	0	Single.	192	0
" "	State street, Harrisburg,	"	1	125	3	"	125	3
" "	Schuylkill, Delaware Extension,	"	2 Pivot—1	192 192	0 0	"	576	0
" "	No. 5, Little Junction,	"	2	82	6	Double.	165	0
" "	Garver's Bridge, Juniata river,	Deck.	4	125	4	"	1,002	8
" "	Mount Union, " "	"	4	3. 123 1. 121	6 6	"	984	0
" "	Mayes, " "	"	5	125	0	"	1,250	0

Iron Bridges Constructed by the Keystone Bridge Company.—Continued.

NAME OF COMPANY.	LOCATION.	Kind of bridge.	Number of spans.	Length of spans.		Single or double track.	Length of single track.	
				Ft.	In.		Ft.	In.
Pennsylvania Railroad,	Johnstown, Conemaugh,	Deck.	5	73	6	Double.	735	0
“ “	Turtle creek,	“	1	106	8	“	213	4
“ “	Shaw's creek,	“	1	75	0	“	150	0
“ “	No. 7, Little Juniata,	“	1	95	0	“	190	0
“ “	No. 10, “ “	“	2	89	0	“	178	0
“ “	No. 3, Summerhill,	“	2	80	0	“	160	0
“ “	Vandevender, Juniata,	“	5	100	0	“	1,000	0
PLATE GIRDER BRIDGES.								
Chicago and North-western Railroad,	Negaunee crossing,		1	51	0	Single.	51	0
Little Miami Railroad,	Cincinnati,		1	33	0	Double.	66	0
Philadelphia, Germantown and Norristown Railroad,	Manayunk,		1	31	6	“	63	0
Keokuk and Hamilton Bridge,	Levee, Keokuk,		1	38	6	“	77	0
New Jersey Railroad and Transportation Company,	Newark,		1	47	0	“	94	0
“ “ “ “	Metuchen,		1	33	0	“	66	0
Pittsburgh, Washington and Baltimore Railroad,	Laurel run,		1	36	0	Single.	36	0
Pittsburgh, Fort Wayne and Chicago Railroad,	Beaver Fall,		1	47	0	Double.	94	0
“ “ “ “	Chicago,		1	33	0	Single.	33	0
Oil Creek and Allegheny River Railroad,	Cherry run,		1	35	6	Double.	71	0
Allegheny Valley Railroad,	Lucesco,		1	35	0	“	70	0
“ “ “	Sandy creek,		1	62	0	“	124	0
“ “ “	Plum creek,		2	53	0	“	212	0
“ “ “	Negley's run,		1	51	6	“	103	0
“ “ “	Puckerty run,		1	66	0	Single.	66	0
“ “ “	Tarrentown,		1	50	0	“	50	0
“ “ “	Chartiers,		1	50	0	“	50	0
Pittsburgh, Washington and Baltimore Railroad,	Soho, Spans 1 and 3,		2	49	6	Double.	198	0
United Railroads of New Jersey,	Metuchen, No. 1,		1	36	0	“	72	0
“ “ “	“ No. 2,		1	36	10	“	73	8
Lehigh and Susquehanna Railroad,	Firmstone, No. 1,		1	15	0	“	30	0
“ “ “	Odenwalden, No. 1,		1	17	0	“	34	0
“ “ “	Stauffer's,		1	19	0	“	38	0
“ “ “	Allentown,		1	21	6	“	43	0
“ “ “	Bethlehem,		1	28	6	Single.	28	6
“ “ “	Lehigh Gap,		1	31	0	“	31	0
“ “ “	Odenwalden road-crossing,		1	28	3	Double.	56	6
“ “ “	Packerton,		1	28	0	“	56	0
“ “ “	Firmstone road-crossing,		1	22	6	“	45	0
“ “ “	Jones' cattle-way,		1	15	6	Single.	15	6
Baltimore and Ohio Railroad,	Parkersburgh,		1	65	6	“	65	6
Connecting Railway, Philadelphia,	Over Richmond Branch,		1	53	9½	Double.	106	7
“ “ “	Over Philadelphia, Germantown and Norristown Railroad,		1	39	4½	“	78	9
Pennsylvania Railroad Extension to Pittsburgh, Cincinnati and St. Louis Railway,	Try street, Pittsburgh,		4	3. 63 1. 47	0 0	“	472	0
Pennsylvania Railroad Extension to Pittsburgh, Cincinnati and St. Louis Railway,	South Pittsburgh,		8	438	0	“	876	0
Pennsylvania Railroad Extension to Pittsburgh, Cincinnati and St. Louis Railway,	Over Pittsburg, Washington and Baltimore Railroad,		4	175	0	“	350	0

Iron (Plate Girder) Bridges Constructed by the Keystone Bridge Company.—Continued.

NAME OF COMPANY.	LOCATION.	Number of spans.	Length of spans. Ft.	Length of spans. In.	Single or double track.	Length of single track. Ft.	Length of single track. In.
Pennsylvania Railroad,	Mayes Bridge canal,	1	73	1	Double.	146	0
“ “	Paxton creek,	1	46	0	“	92	0
“ “	Little Conestoga,	1	39	0	“	78	0
“ “	No. 4, Little Juniata,	4	2. 53 1. 52 1. 50	4 8 8	“	420	0
“ “	Haverford street, Philadelphia,	1	58	0	4 tracks.	232	0
“ “	No. 1, Hestonville,	1	37	0	Double.	74	0
“ “	No. 2, “	1	33	6	“	67	0
“ “	Conemaugh,	2	1. 69 1. 59	5½ 7	“	258	0
“ “	Strickler's,	....	1. 50	0	......	100	0
Northern Central Railway,	Jail bridge, Baltimore,	1	122	0	“	244	0
“ “ “	Race “ “	1	24	6	“	49	0
“ “ “	No. 3,	2	52	3	“	209	0
“ “ “	St. James',	2	54	0	Single.	108	0
“ “ “	Magraw's,	1	33	0	Double.	66	0
“ “ “	Ryder's,	1	33	0	“	66	0
“ “ “	Nerby's,	1	28	0	“	56	0
“ “ “	No. 94,	1	26	6	“	53	0
“ “ “	No. 148,	2	63	3	“	253	0

Triangular Girders.

Error

NAME OF COMPANY.	LOCATION.	Number of spans.	Length of spans. Ft.	Length of spans. In.	Single or double track.	Length of single track. Ft.	Length of single track. In.
Lehigh and Susquehanna Railroad,	Easton Viaduct,	8	~~428~~	~~3½~~	Single.	428	3½
“ “ “	Snufftown,	1	48	6	“	48	6
“ “ “	Lehigh Gap,	1	46	6	“	46	6
“ “ “	Coplay,	2	1. 49 1. 66	6 0	“	115	6
“ “ “	Poko Poko,	2	50	0	Double.	200	0
“ “ “	Monocacy,	1	57	0	“	114	0
“ “ “	Catasauqua,	1	35	6	Single.	35	6
“ “ “	No. 7, Delaware bridge,	1	37	0	“	37	0
Pittsburgh, Fort Wayne and Chicago Railroad,	No. 31, Sugar creek,	1	47	0	“	47	0
“ “ “ “	No. 27, Newman's creek,	1	47	0	“	47	0
Northern Central Railway,	Nos. 173 and 174,	2	58	0	Double.	232	0
Kansas City Bridge,	Span No. 1,	1	70	0	Single.	70	0
Pennsylvania Railroad,	State street, Harrisburg, roadway,	1	58	0	Double.	116	0
“ “	Villa Nova, roadway,	1	48	6	Single.	48	6
“ “	West Chester Intersection, roadway,	1	48	6	“	48	6
“ “	Parksburg, No. 128, roadway,	3	46	6	“	139	6
“ “	Bell's Mills, roadway,	1	56	6	“	56	6
“ “	Neff's, 1 and 2, roadway,	2	56	6	“	113	0
Central Railroad of New Jersey,	Bergen street,	2	49	0	Triple.	294	0
“ “ “ “	Linnet street,	2	42	9	“	256	6

Total length Iron Bridges, equivalent single track, . . 64,900 0

LIST OF WOODEN BRIDGES BUILT BY KEYSTONE BRIDGE COMPANY.

NAME OF COMPANY.	NAME OF BRIDGE.	Number of spans.	Length of spans.		Single or double.	Total length.	
			Ft.	In.		Ft.	In.
Philadelphia and Erie Railroad,	Sunbury,	6	161	0	1	966	0
“ “ “	Northumberland,	7	153	0	. .	1,071	0
“ “ “	Muncy dam,	7	150	0	. .	1,050	0
“ “ “	Williamsport,	7	156	0	1	1,092	0
“ “ “	Lycoming creek,	2	110	0	1	220	0
“ “ “	Bald Eagle,	3	156	0	1	468	0
“ “ “	Warren,	3	165	0	1	495	0
“ “ “	Muncy,	1	161	0	1	161	0
“ “ “	Westport,	1	162	0	1	162	0
“ “ “	Keating,	2	152	6	. .	305	0
Northern Central Railway,	Codorus,	2	150	0	. .	300	0
“ “ “	Gut,	2	150	0	. .	300	0
“ “ “	Conawagua,	2	150	0	. .	300	0
“ “ “	Dauphin,	18	16. 210 1. 100 1. 130	0 0 0	1	3,590	0
“ “ “	Heck's Furnace,	1	138	6	2	138	6
“ “ “	Penn Yan,	2	120	0	1	240	0
“ “ “	Clark's creek,	1	138	6	2	138	6
Williamsport and Elmira Railroad,	Bridge No. 1,	1	171	0	1	171	0
“ “ “	“ “ 2,	1	228	2	1	228	2
“ “ “	“ “ 3,	1	140	10	1	140	10
“ “ “	“ “ 7,	1	195	6	1	195	6
“ “ “	“ “ 9,	1	162	0	1	162	0
“ “ “	“ “ 10,	1	160	0	1	160	0
“ “ “	“ “ 11,	2	192 184	0 0	1	376	0
“ “ “	“ “ 13,	1	210	0	1	210	0
“ “ “	“ “ 14,	1	147	0	1	147	0
“ “ “	“ “ 15,	1	195	6	1	195	6
“ “ “	“ “ 16,	1	107	0	1	107	0
“ “ “	“ “ 20,	1	84	8	1	84	8
“ “ “	“ “ 21,	1	112	6¼	1	112	6¼
“ “ “	“ “ 22,	1	104	0	1	104	0
“ “ “	“ “ 23,	1	133	0	1	133	0
“ “ “	“ “ 24,	1	128	3	1	128	3
“ “ “	“ “ 25,	1	158	0	1	158	0
“ “ “	“ “ 26,	1	92	2	1	92	2
Shamokin Railroad,	Bridge No. 1,	2	120 119	6 5	. .	339	11
“ “	“ “ 2,	1	78	8	. .	78	8
“ “	“ “ 3,	2	120 119	6 1	. .	339	7
“ “	“ “ 4,	1	119	5	. .	119	5
“ “	“ “ 5,	2	72 72	4 1	. .	144	5
Allegheny Valley Railroad,	Clarion,	2	180	0	1	360	0
“ “ “	East Sandy,	2	127	0	1	254	0
“ “ “	Mahoning,	2	154	0	1	308	0
“ “ “	Red Bank,	2	162	0	1	324	0

List of Wooden Bridges Built by Keystone Bridge Company.—Continued.

NAME OF COMPANY.	NAME OF BRIDGE.	Number of spans.	Length of spans.		Single or double.	Total length.	
			Ft.	In.		Ft.	In.
Allegheny Valley Railroad,	Oil City,	3	207 218 207	11 5 11	1	634	3
Bennett's Branch, Western Division,	Mortimer's run,	1	60	0	2	60	0
“ “ “ “	Leatherwood,	1	50	0	1	50	0
“ “ “ “	Bethlehem,	1	180	0	1	180	0
“ “ “ “	Pine run,	1	50	0	1	50	0
“ “ “ “	Indiantown,	1	50	0	1	50	0
“ “ “ “	Beaver run,	1	50	0	1	50	0
“ “ “ “	Robinson's Loop,	3	65	0	1	195	0
“ “ Middle Division,	Bridge No. 1,	2	65	0	1	130	0
“ “ “ “	“ “ 2,	2	80	0	1	160	0
“ “ “ “	“ “ 3,	2	70	0	1	140	0
“ “ “ “	“ “ 4,	3	70	0	1	210	0
“ “ “ “	“ “ 5,	3	65	0	1	195	0
“ “ “ “	Falls creek,	1	70	0	1	70	0
“ “ “ “	Bridge No. 6,	3	80 2. 70	0 0	1	220	0
“ “ “ “	“ “ 6½,	1	50	0	1	50	0
“ “ “ “	“ “ 7,	2	80	0	1	160	0
“ “ “ “	“ “ 8,	3	80	0	1	240	0
“ “ “ “	“ “ 8½,	1	60	0	1	60	0
“ “ “ “	“ “ 9,	2	80	0	1	160	0
“ “ “ “	“ “ 10,	3	65	0	1	195	0
“ “ “ “	“ “ 11,	3	80 2. 70	0 0	1	220	0
“ “ “ “	“ “ 12,	3	80	0	1	240	0
“ “ “ “	“ “ 13,	3	65	0	1	195	0
“ “ East “	Meadic's run,	1	84	0	1	84	0
“ “ “ “	Laurel run,	1	73	0	1	73	0
“ “ “ “	Bridge west of Big Cut,	2	73	0	1	146	0
“ “ “ “	“ east “ “	1	113	9	1	113	9
“ “ “ “	Bridge No. 4,	1	75	8	1	75	8
“ “ “ “	“ “ 3,	1	75	8	1	75	8
“ “ “ “	“ “ 2,	2	156	8	2	313	4
“ “ “ “	“ “ 1,	2	146	5	2	292	10
“ “ Middle “ (All single track,)		2	30	0	. .	60	0
“ “ “ “ “ “ “		6	25	0	. .	150	0
“ “ “ “ “ “ “		4	20	0	. .	80	0
West Pennsylvania Railroad,	Conemaugh, Section 3,	4	143 141 140	6 0 0	1	504	6
“ “ “	“ “ 7,	3	141	0	1	423	0
“ “ “	“ “ 8,	3	140	0	1	420	0
“ “ “	Wolford's run,	2	242	0	1	484	0
“ “ “	Blairsville,	3	199	9	1	599	3
“ “ “	Beaver run,	2	96	3	1	192	6
“ “ “	Livermore, Section 6,	4	140	0	1	560	0
“ “ “	Short span, “ 3,	1	83	7	1	83	7
“ “ “	Freeport,	5	160	0	1	800	0

List of Wooden Bridges Built by Keystone Bridge Company.—Continued.

NAME OF COMPANY.	NAME OF BRIDGE.	Number of spans.	Length of spans.		Single or double.	Total length.	
			Ft.	In.		Ft.	In.
West Pennsylvania Railroad,	Saltsburg,	6	136 135 159 152 159 159	6 0 11½ 8¾ 8 0	1	902	10¼
“ “ “	Buffalo creek,	. .	. . . .		. .	213	7
“ “ “	Bull creek,	. .	. . . .		. .	44	0
“ “ “	Deer creek,	. .	. . . .		. .	88	0
Lehigh and Susquehanna Railroad,	Turnhole,	6	1. 125 2. 76 3. 133	0 8 6	1	678	10
“ “ “	Lehighton,	1	113	8	1	113	8
“ “ “	Parryville,	1	163	0	1	163	0
“ “ “	Wiseport,	3	146	3	1	438	9
“ “ “	Swartz's dam,	1	152	0	1	152	0
“ “ “	Wheeler's Lock,	1	150	0	1	150	0
“ “ “	Bethlehem, Canal S,	1	82	0	1	82	0
Delaware Division, Pennsylvania Canal,	Tohican Aqueduct,	3	66	0	1	198	0
“ “ “ “	Tinicum “	2	56	0	1	112	0
“ “ “ “	Gallow's Run Aqueduct,	2	57	0	1	114	0
“ “ “ “	Durham “	2	57	9	1	114	9
Cumberland Valley Railroad,	Powell's Bend,	7	123 4. 143 148 165	0 9 0 9	1	1,011	9
Mifflin and Centre County Railroad,	Lewistown canal,	1	55	6	1	655	6
“ “ “ “	Lewistown river,	4	152	8	1	310	8
Tyrone and Clearfield Railroad,	Clearfield creek,	2	150	0	1	00	0
“ “ “	Roaring run,	1	42	6	1	42	6
Williamsburg Branch, Pennsylvania Railroad,	Piney creek,	1	82	3	1	82	3
“ “ “	Juniata,	2	103	4	1	206	8
Columbia and York Railroad,	Columbia,	28	192	0	1	5,366	0
Lewisburg and Centre County Railroad,	Juniata river,	2	102	9	1	205	6
Harrisburg and Potomac Railroad,	Yellow Breeches,	1	123	3	1	123	3
Pittsburgh, Cincinnati and Chicago Railroad,	Bridge No. 30,	. .	. . . .		. .	400	0
Miscellaneous,	Johnstown Manufacturing Company,	2	82	5	1	164	10
“	Turtle creek,	1	117	0	1	117	0
“	Brady's Bend,	5	4. 150 1. 200	0 0	1	808	0
“	Sharpsburg and Lawrenceville Bridge Company,	5	180	0	1	900	0
“	Thomson's run,	1	60	0	1	60	0
“	Kansas City,	2	198 248	0 0	1	446	0
“	Lewisburg,	. .	. . . .		. .	1,283	0
Baltimore and Potomac Railroad,	Rogue Harbor,	1	52	0	1	52	0
“ “ “	Herbert's run,	1	63	0	1	63	0
“ “ “	Little Patuxent,	1	175	9	1	175	9
“ “ “	Big Patuxent,	2	145	6	1	291	0
“ “ “	Patapsco,	4	136	0	1	544	0

List of Wooden Bridges Built by Keystone Bridge Company.—Continued.

NAME OF COMPANY.	NAME OF BRIDGE.	Number of spans.	Length of spans. Ft.	Length of spans. In.	Single or double.	Total length. Ft.	Total length. In.
Baltimore and Potomac Railroad,	Long bridge, north channel,	3	137	6	2	412	6
“ “ “	“ “ south “	9	137	6	2	1,237	6
“ “ “	“ “ east branch,	1	101	9	1	101	9
“ “ “	“ “ Spans Q and R,	2	82	0	2	164	0
“ “ “	“ “ pivot spans,	1	141	2	1	141	2
Oil Creek and Allegheny River Railroad,	Oleopolis,	1	120	0	1	120	0
“ “ “ “	Rouseville,	2	147	0	1	294	0
“ “ “ “	Oil City,	2	146	0	1	292	0
“ “ “ “	Hidetown,	1	80	0	1	80	0
Alexandria and Fredericksburg Railroad,	Cameron run,	1	104	2	1	104	2
“ “ “	Pohick creek,	1	92	0	1	92	0
“ “ “	Accotink,	1	76	0	1	76	0
Pittsburgh, Cincinnati and St. Louis Railway,	Monongahela,	5	Long span,		2	951	0
		5	Short span,			427	0
“ “ “ “	Bailey's	1	90	0	1	90	0
“ “ “ “	Ming's creek,	1	150	0	1	150	0
“ “ “ “	“ “ No. 2,	1	150	0	1	150	0
“ “ “ “	Saw Mill run,	1	234	0	1	234	0
					Total length Wooden Bridges,	47,600	0

THE KEYSTONE BRIDGE COMPANY,

IRON FOUNDERS AND MACHINISTS

CASTINGS OF EVERY DESCRIPTION FURNISHED TO ORDER

EQUAL TO BEST PHILADELPHIA CASTINGS.

CHILLED AND SAND ROLLS,
PULLEYS,
HANGERS AND GEARING,
BRIDGE CASTINGS,
ROLLING-MILL CASTINGS,
MACHINE CASTINGS,

ROLL TURNING,
FORGING,
SMITHING,
GENERAL MACHINE-WORK,
MACHINISTS' TOOLS.

◆

Our Shops are fully equipped with superior Lathes, Planers, &c., used in the construction of the St. Louis Bridge, and every appliance requisite for the execution of general machine and bridge work.

CARNEGIE, KLOMAN & CO.

PROPRIETORS

UNION IRON MILLS,

OF PITTSBURGH, PENNSYLVANIA,

SOLE MANUFACTURERS, UNDER OUR OWN PATENTS, OF

IMPROVED ROLLED-IRON I BEAMS AND [BARS.

ALSO, MANUFACTURERS OF

BEST QUALITY OF LOCOMOTIVE AND CAR AXLES,

(KLOMAN BRAND,)

ROUND AND OCTAGONAL HOLLOW WROUGHT-IRON COLUMNS

AND

UPSET BRIDGE LINKS,

MERCHANT BAR, OF ALL DESCRIPTIONS; HAMMERED AND ROLLED AXLES, FISH-PLATES AND BOLTS TO FIT ALL PATTERNS OF RAILS, BRIDGE IRON, BOLTS, &c.

General Office and Works,
PITTSBURGH, PA.

Western Office,
211 WASHINGTON AVENUE, ST. LOUIS, MO.

New York Office,
NO. 57 BROADWAY.

UPSET CHORD LINKS.

THESE LINKS WILL BE FURNISHED IN ANY LENGTH UP TO 50 FEET. WIDTH OF HEADS, ANY SIZE UP TO 20 INCHES.

◆

THE KEYSTONE BRIDGE COMPANY HAS THE EXCLUSIVE RIGHT TO USE

UPSET LINKS FOR BRIDGES AND OTHER STRUCTURES.

◆

THEY HAVE ON HAND ABOUT 500 TONS OF

SUPERIOR DOUBLE-ROLLED LINKS,

6 inches by 1 inch and 7 inches by 1 inch, in lengths of 27 feet 6 inches between centres of eyes,—eyes 3½ inches in diameter.

These Links are of **SUPERIOR QUALITY**, having been thoroughly tested, and will be made into lengths of about 12 feet, if desired, and supplied to bridge-builders and others at greatly reduced rates. They have been painted, and are first-class in every respect.

◆

THESE LINKS ARE WORTHY THE ATTENTION OF BRIDGE-BUILDERS.

TESTING-MACHINES,

HYDRAULIC PRESSES.

THE COMPANY OFFERS FOR SALE, VERY LOW,

ONE HYDRAULIC TESTING-MACHINE,

USED IN TESTING STEEL FOR THE ST. LOUIS BRIDGE.

Diameter of Ram, 24 inches; stroke, 18 inches. Steel Pulling-bolt, 6 inches diameter, passes through the rear end of the Ram for making tests of tensile strength; Steel Tension Side Bars, 40 square inches to each side; Compression Timbers; Foundation Timbers; Clamps and Bands for connecting specimens 5¾ inches diameter, also, for small test specimens; Lengthening-bars, Wrenches, and extra fittings; Three Eccentric Hydraulic Pumps and Steam-pump; Hydraulic Pipe and Couplings. This apparatus is adapted for tests of 800 tons in compression and 520 tons in tension. Will be sold greatly below cost, as we have other machines in use at our works.

ALSO,

EIGHT HYDRAULIC RAMS,

USED IN THE ERECTION OF ST. LOUIS BRIDGE.

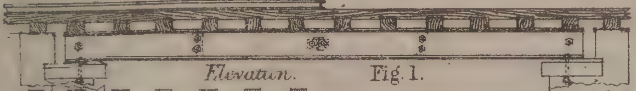
Diameter, 11 inches; stroke, 13 inches. Provided with jaws for tie-bolts, and designed to be used in testing. These Rams have been subjected to proof-strain of 5000 pounds per square inch.

FIVE HYDRAULIC HAND-PUMPS AND FOUR HYDRAULIC GAUGES,

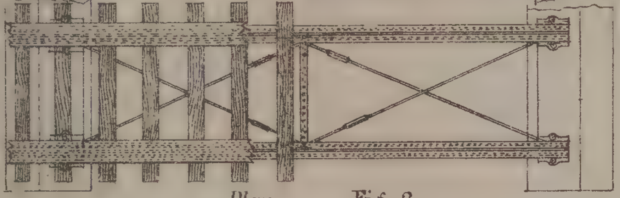
With cross-heads and weights. These Rams will be sold very low. They are of superior quality, and well worthy the attention of parties desiring to erect testing-apparatus, presses, &c.

Plate 1.

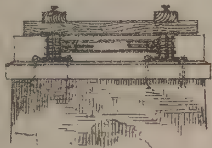
DIVISION A. *Solid Girders. Spans 10 ft to 20 ft.*



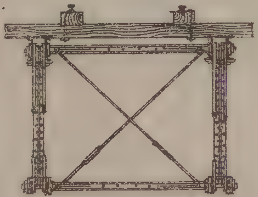
Elevation. Fig. 1.



Plan. Fig. 2.

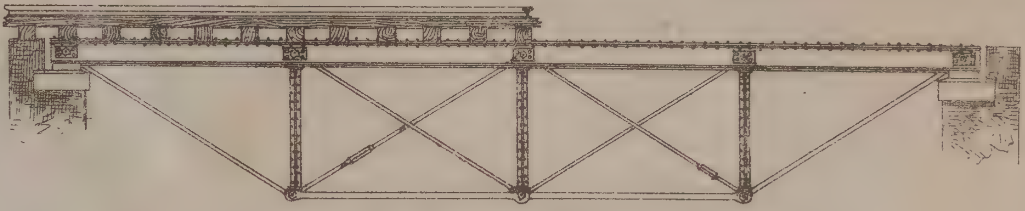


Section. Fig. 3.

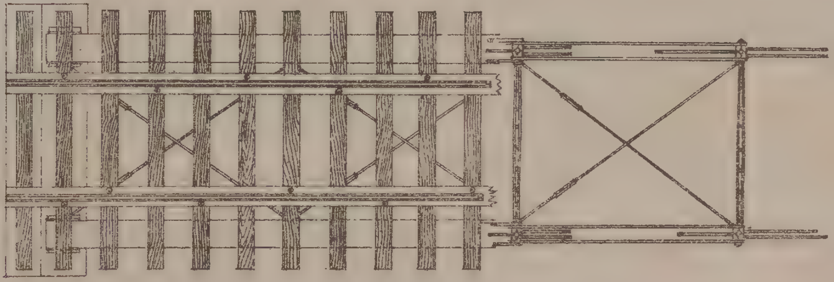


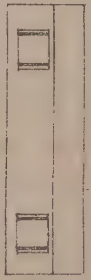
Section of Trussed Girder. Fig. 6.

DIVISION B. *Trussed Girder. Spans 20 ft to 60 ft.*



Elevation. Fig. 4.





Plan. Fig. 5.

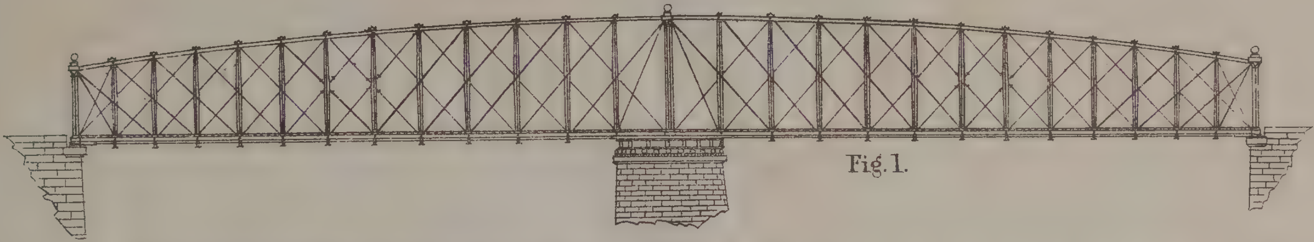


Fig. 1.

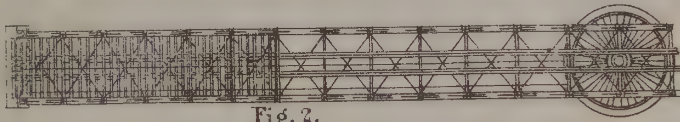


Fig. 2.

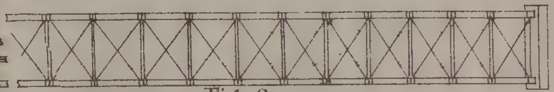


Fig. 3.

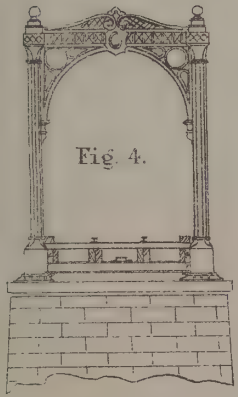


Fig. 4.

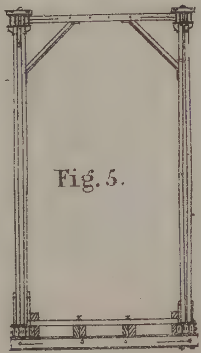


Fig. 5.

[redacted]

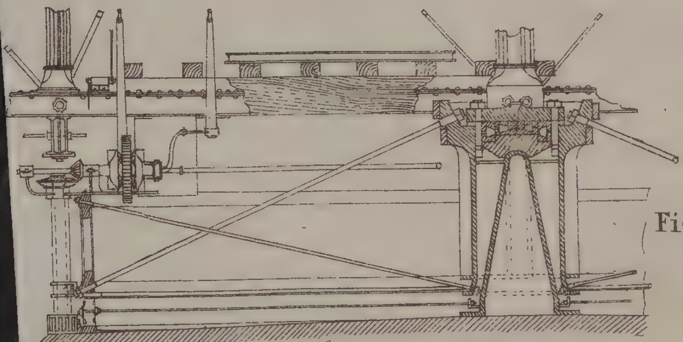


Fig. 7.

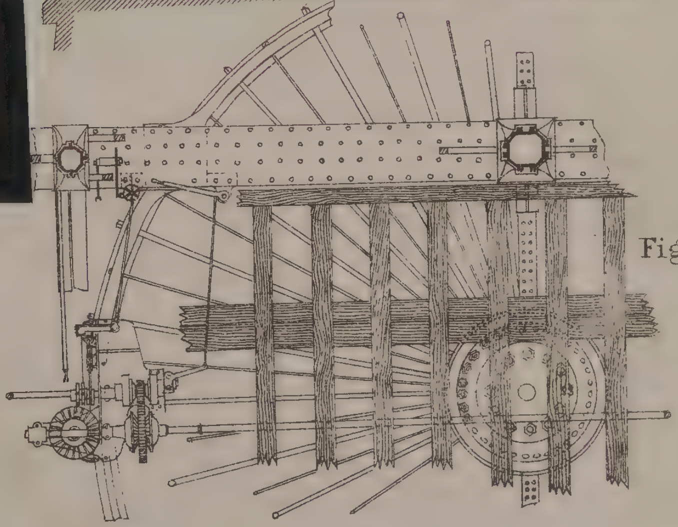


Fig. 8.

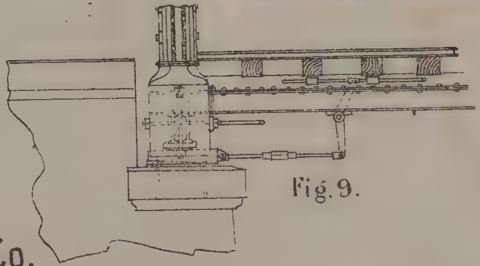


Fig. 9.

DIVISION G.

PIVOT BRIDGES.

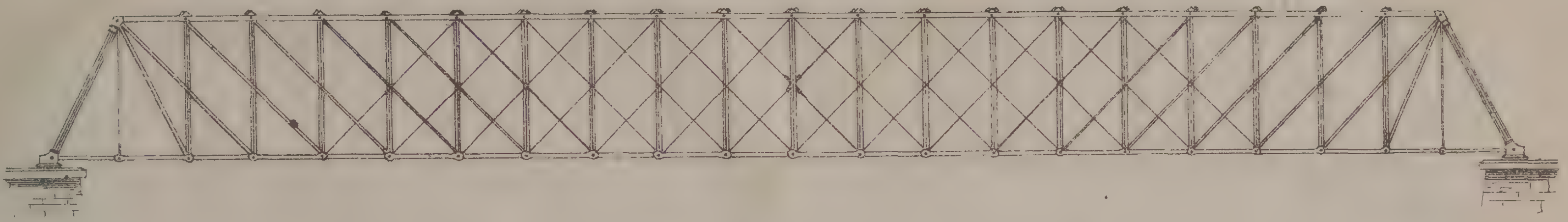
Constructed by the

KEYSTONE BRIDGE CO.

Pittsburgh, Pa.

PRINTED BY H. J. TOUDY & CO. PHILA.

Fig. 1.



DIVISION H.

LONG SPAN BRIDGES,

Spans 250 ft to 500 ft.

Constructed by the

KEYSTONE BRIDGE COMP^Y

Pittsburgh, Pa.

NEWPORT & CINCINNATI	420 FT.
PARKERSBURGH	350 ..
BELAIR.	350 ..
STEUBENVILLE.	320 ..

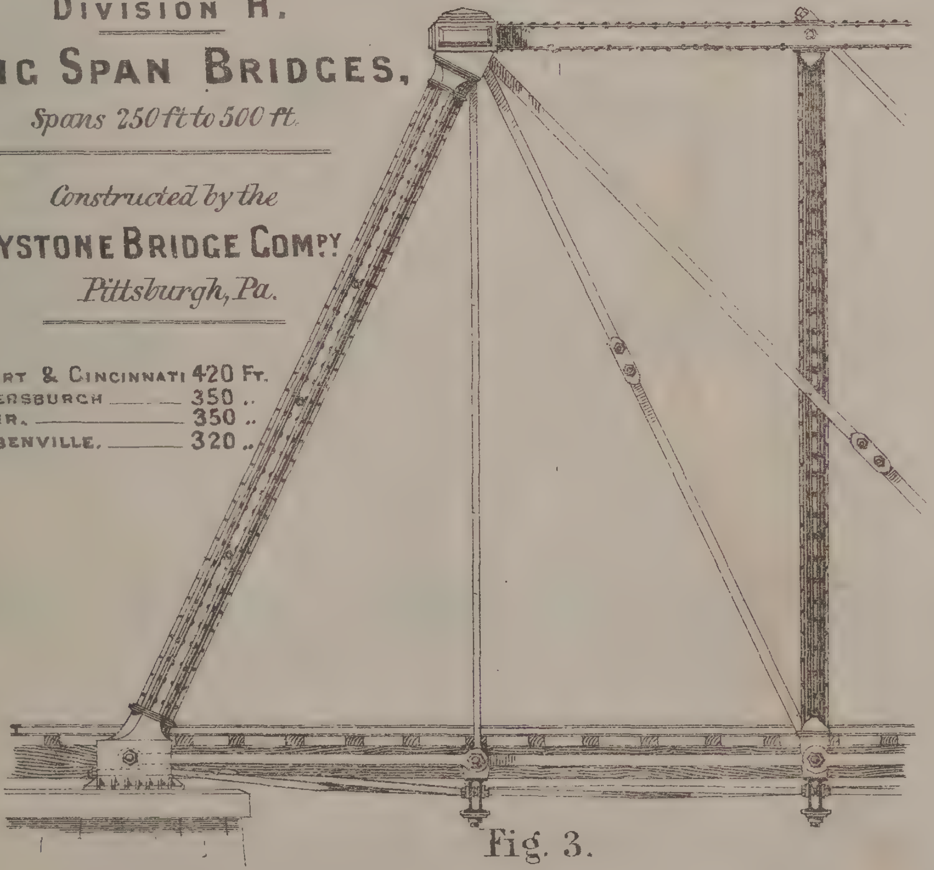


Fig. 3.

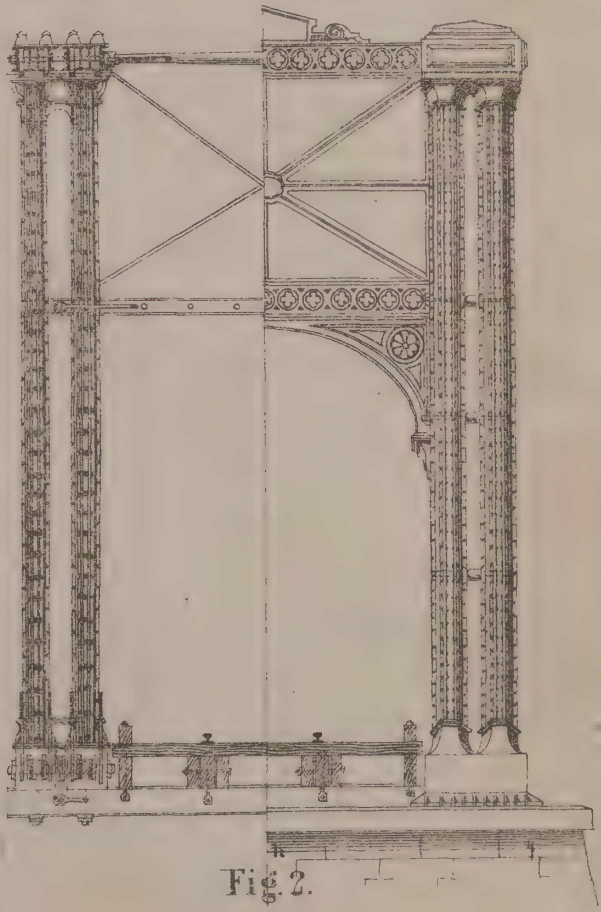


Fig. 2.

Ben Linfoot, Lith, Phil^a.

Printed by H. J Toudy & Co. Phila.

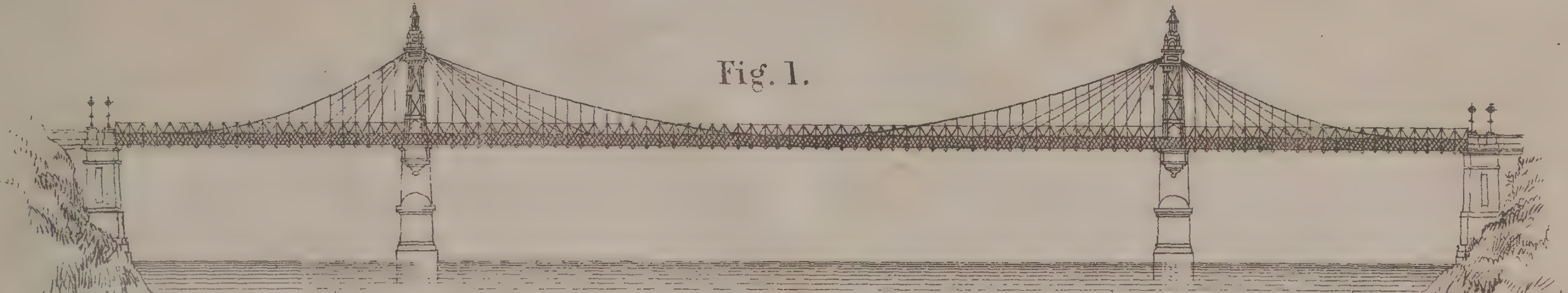


Fig. 1.

SUSPENSION BRIDGES.

Designed & Constructed by the
KEYSTONE BRIDGE CO.
Pittsburgh, Pa.

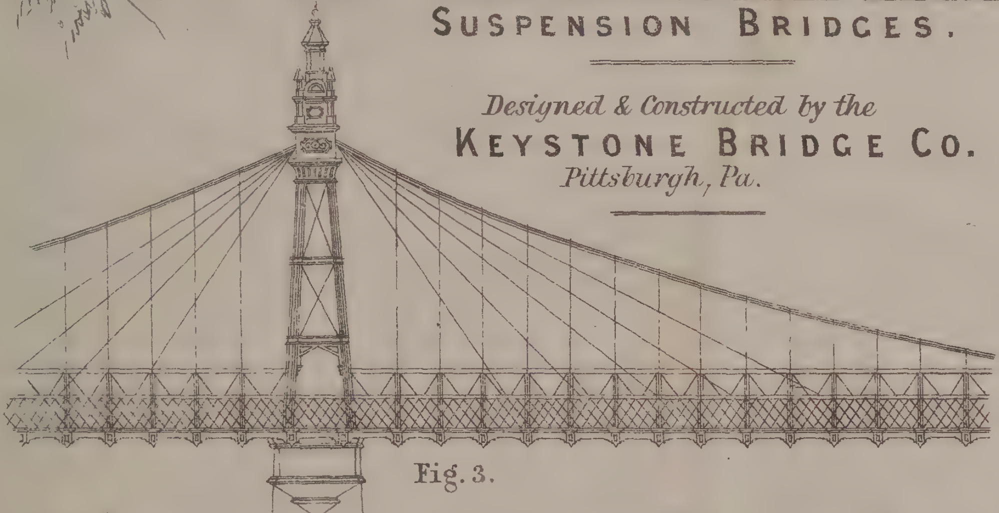


Fig. 3.

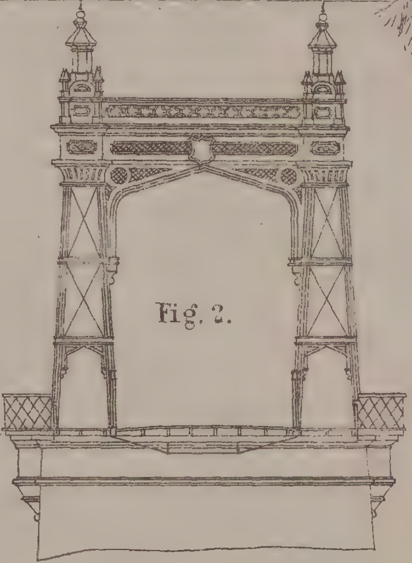
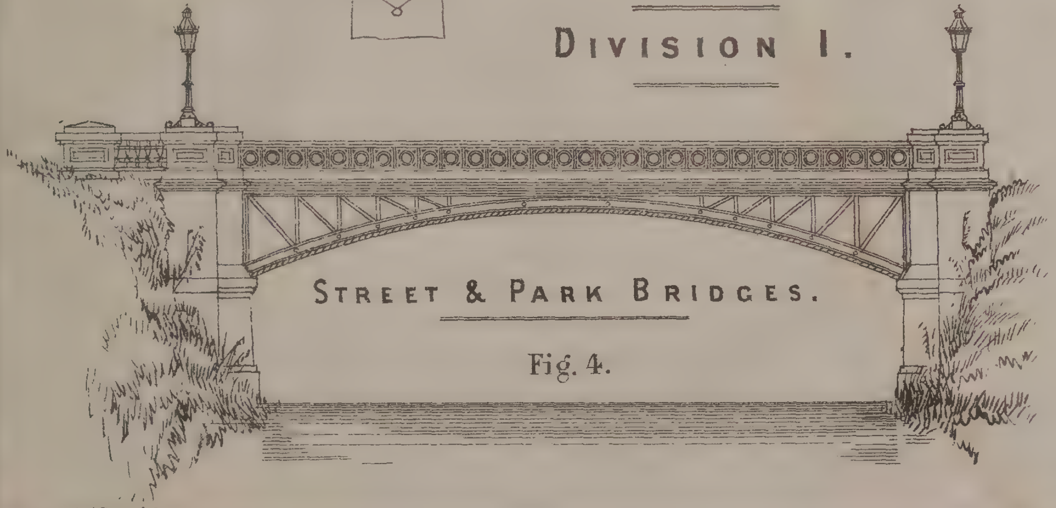


Fig. 2.

DIVISION I.



STREET & PARK BRIDGES.

Fig. 4.

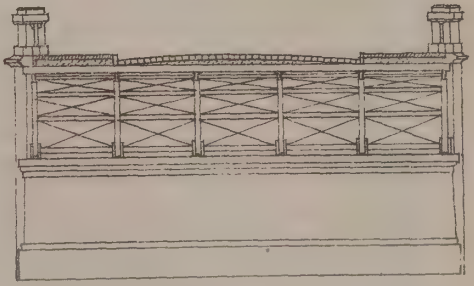


Fig. 5.

Printed by H. J. Toudy & Co Phila.

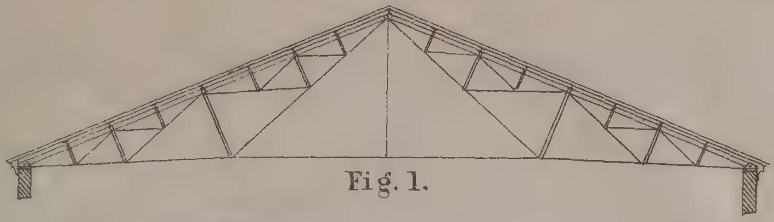


Fig. 1.

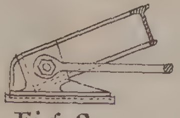
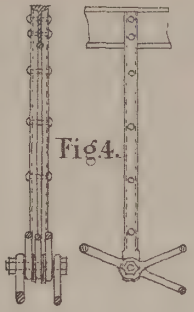


Fig. 3.



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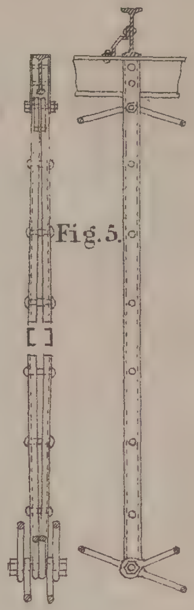


Fig. 5.

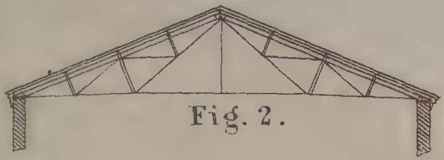


Fig. 2.

IRON ROOF TRUSSES
for
SHOPS, ENGINE HOUSES, IRON & STEEL WORKS, &c.

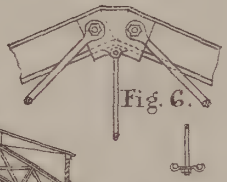
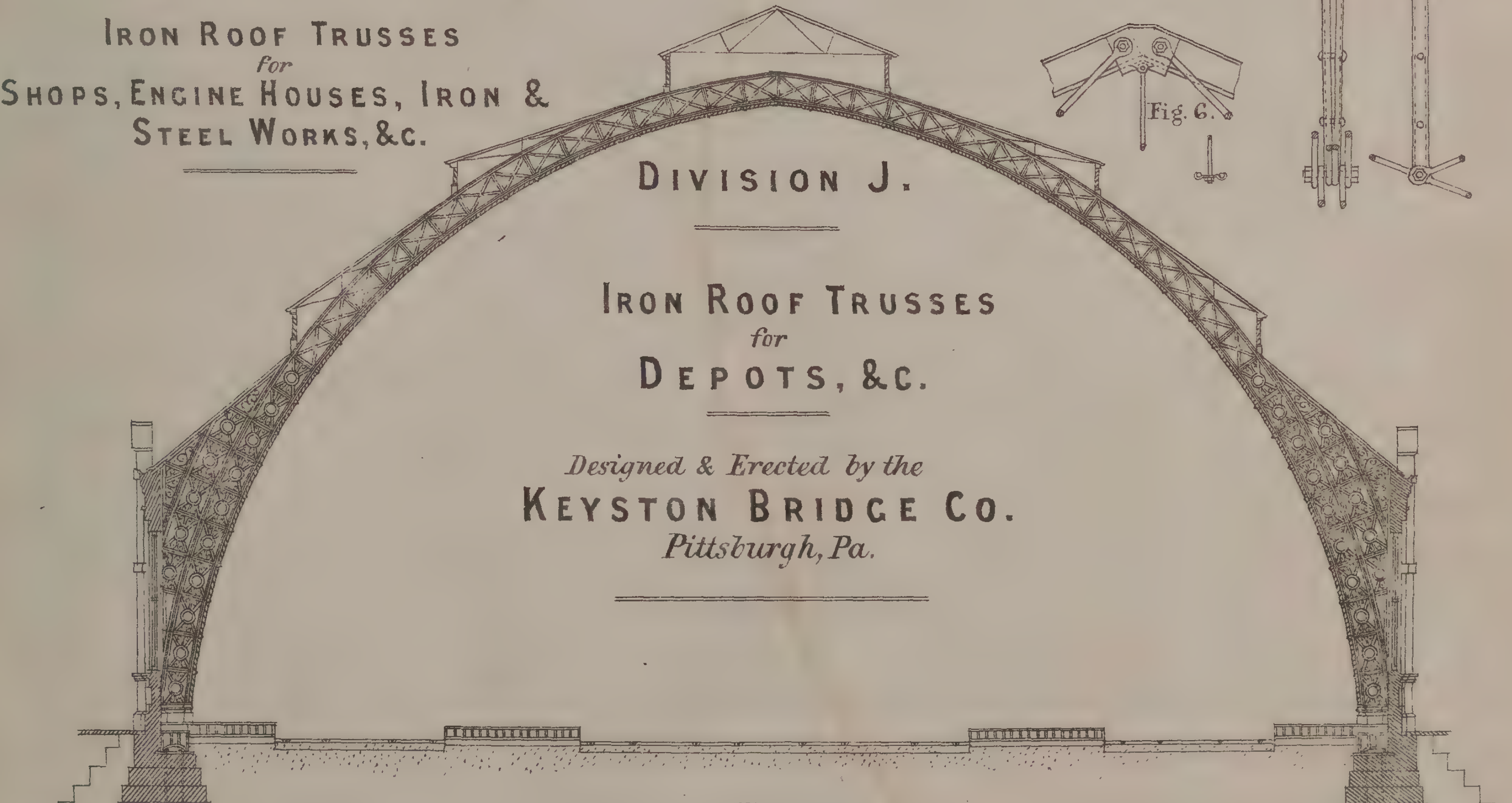


Fig. 6.



DIVISION J.

IRON ROOF TRUSSES
for
DEPOTS, &c.

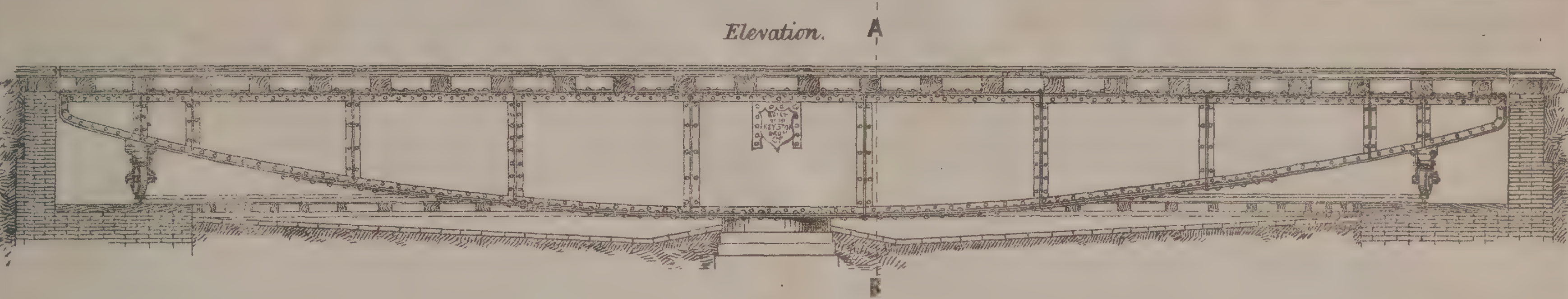
Designed & Erected by the
KEYSTON BRIDGE CO.
Pittsburgh, Pa.

Fig. 7.

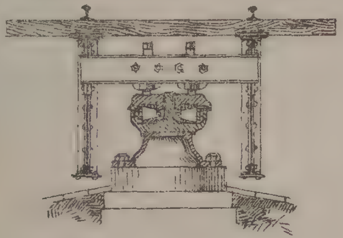
PRINTED BY H. J. TOUDY & Co. PHILA.

BEN LINFOOT, LITH

Elevation.



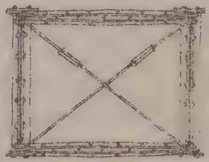
Section at Centre.



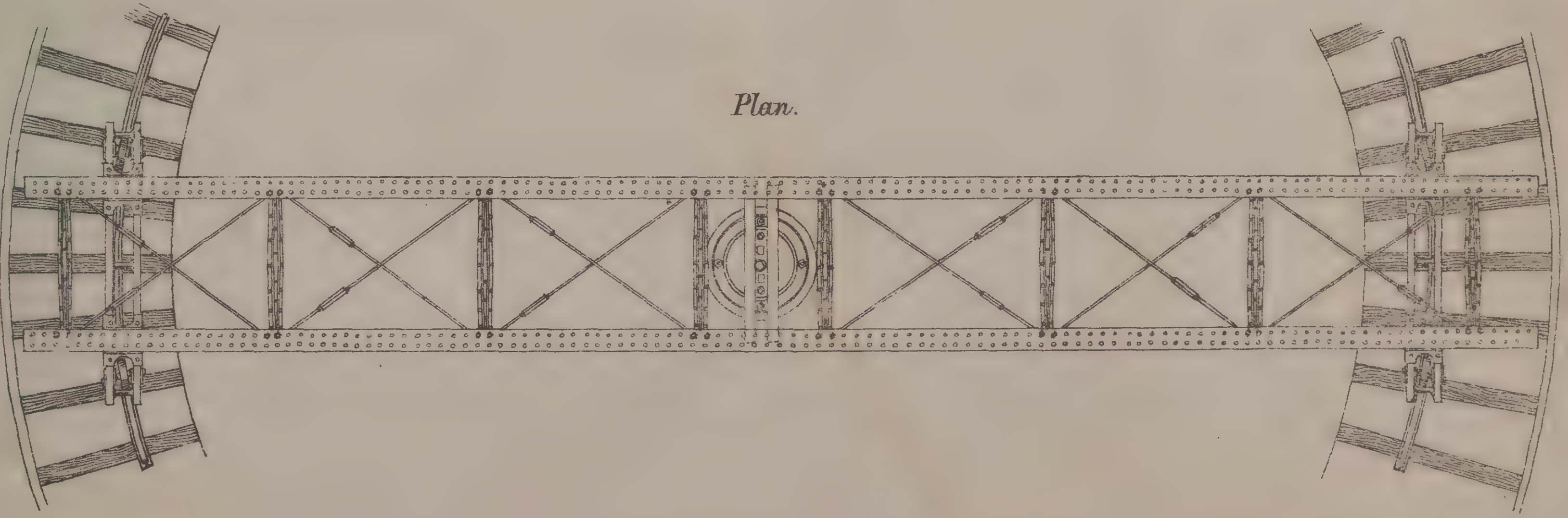
WROUGHT IRON TURNTABLE
with
J. L. Piper's Improved Centre
PATENTED OCT. 22ND 1872.

Constructed by the
KEYSTONE BRIDGE CO.
Pittsburgh, Pa.

Section at A.B.



Plan.



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BEN LINFOOT, LITH. 1873.

Fig. 1 Total Load 40 Tons.

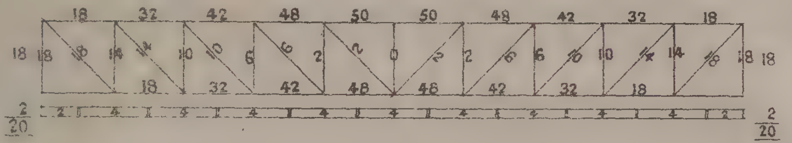


Fig. 2. Total Load 10 Tons.

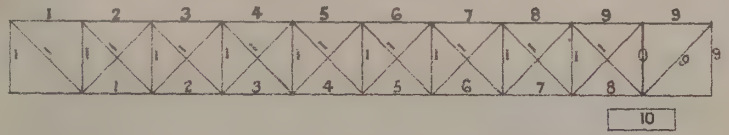


Fig. 3. Total Load 20 Tons.

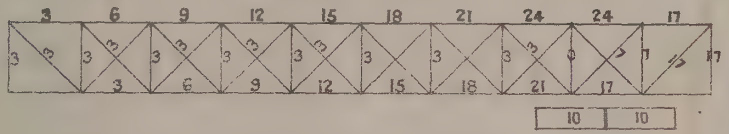


Fig. 4. Total Load 50 Tons.

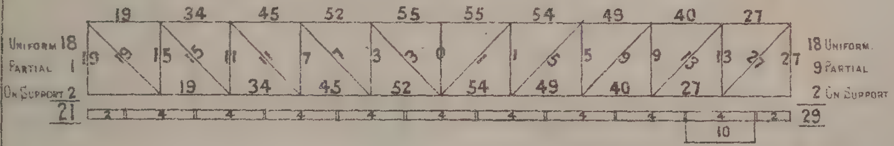


Fig. 5. Total Load 60 Tons.

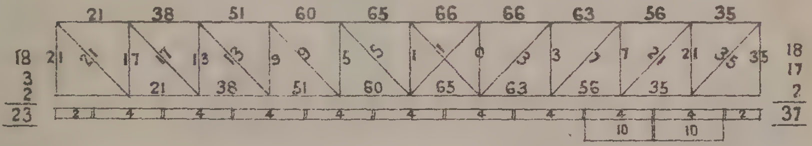


Fig. 6. Total Load 70 Tons.

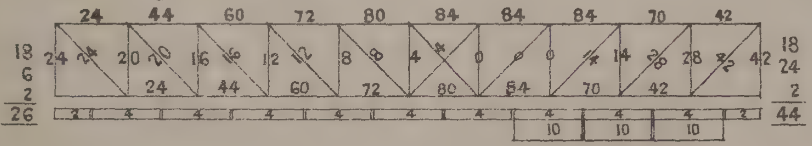


Fig. 7. Total Load 80 Tons.

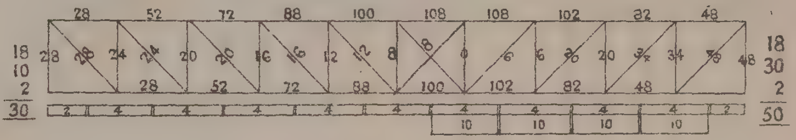


Fig. 8. Total Load 90 Tons.

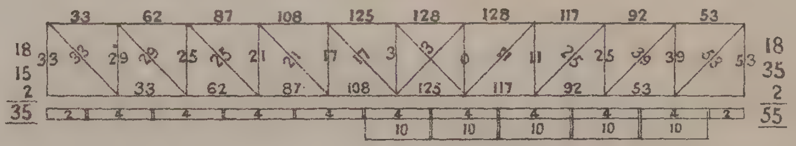


Fig. 9. Total Load 100 Tons.

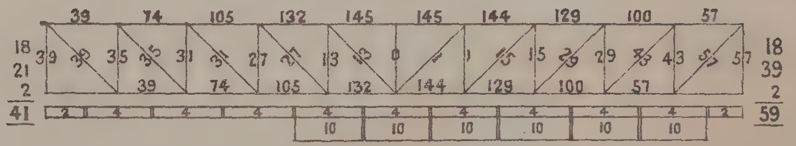


Fig. 10. Total Load 110 Tons.

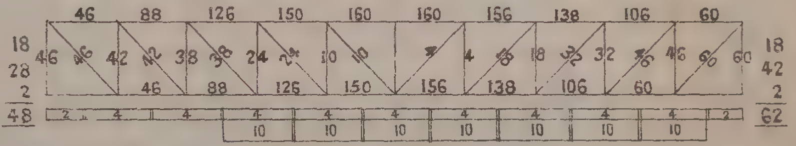


Fig. 11. Total Load 120 Tons.

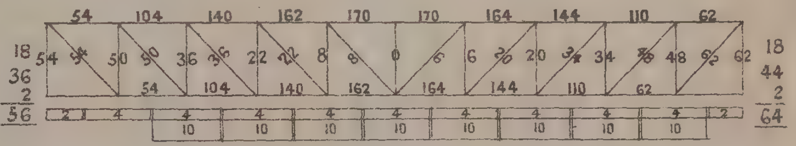
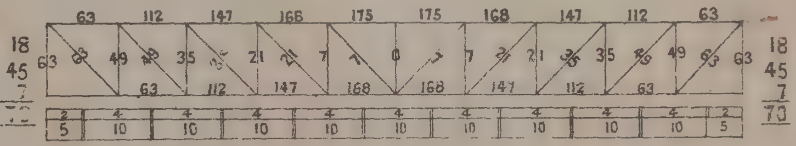


Fig. 12. Total Load 140 Tons.



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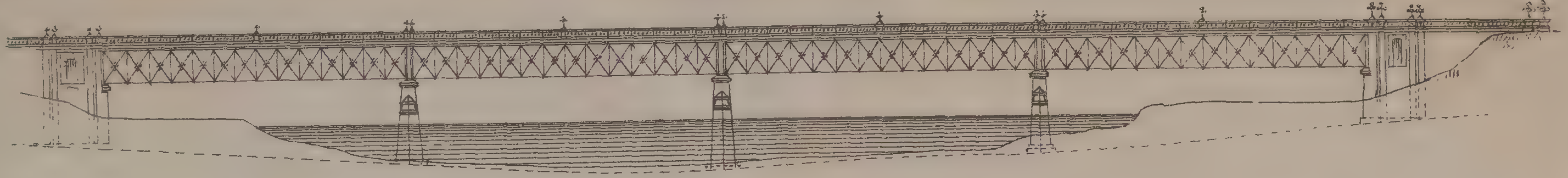
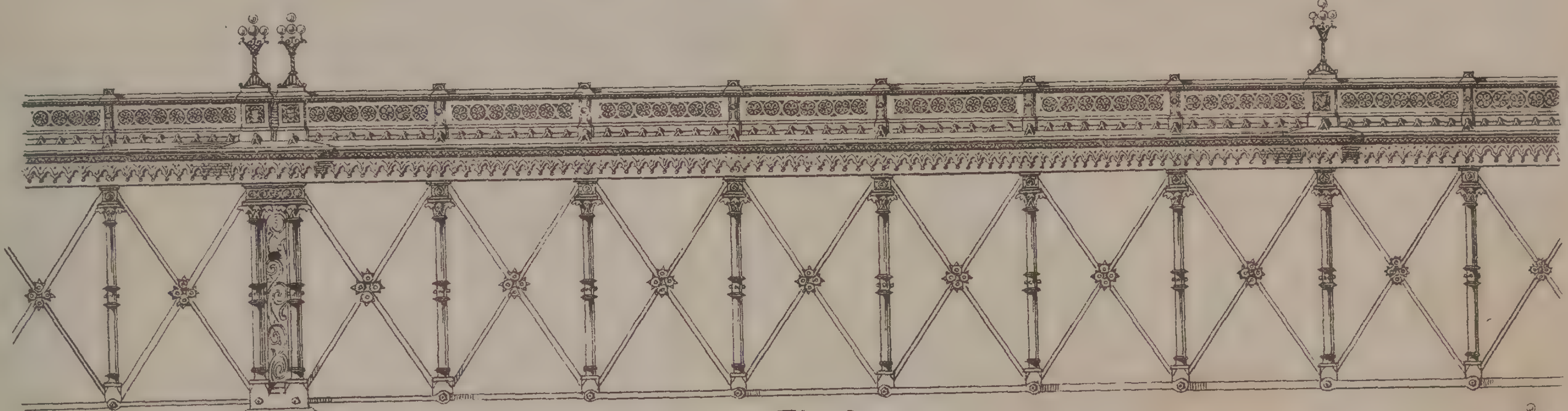


Fig. 1



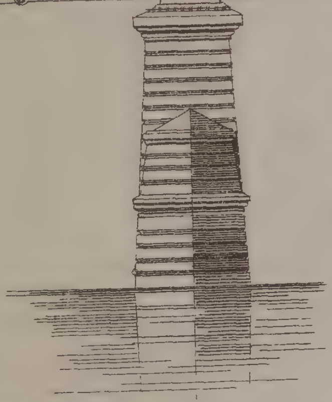


Fig. 2.

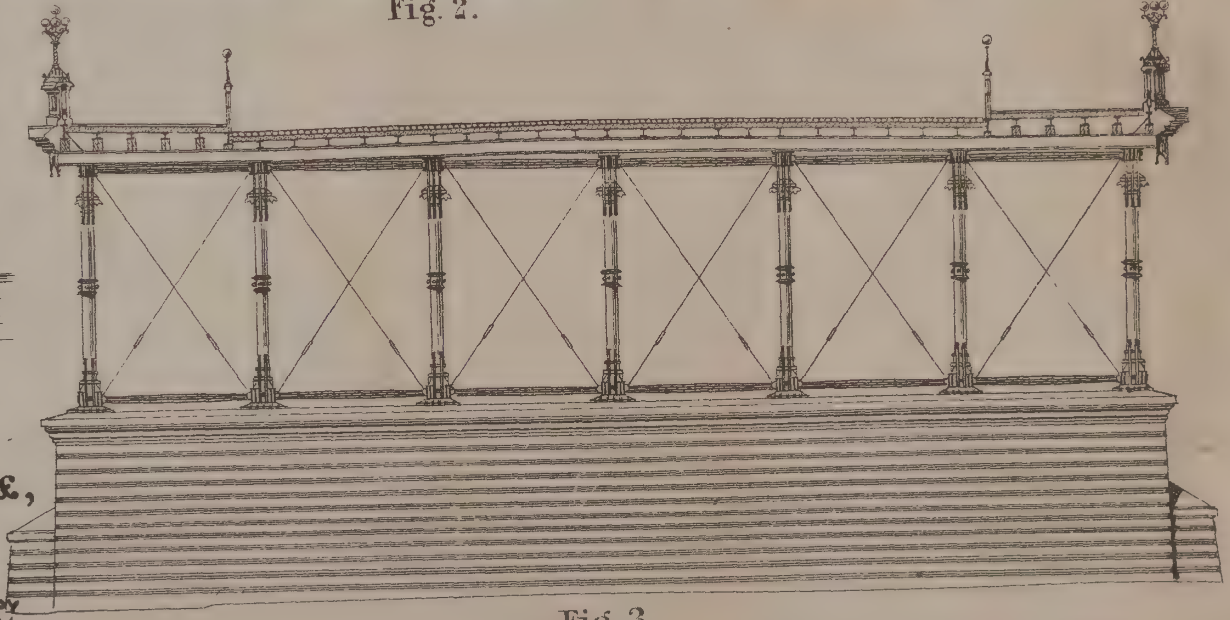


Fig. 3.

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Phila. da Pa.
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KEYSTONE BRIDGE COMPY
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